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Removal Notice.

The offices of The Engineering Record have been removed to the new building of the McGraw Realty Company at 239 West 39th Street, New York. This structure, named the Thirty-ninth Street Building, is but five minutes' walk from the Engineering Societies' Building, and is the most notable example of reinforced concrete construction in the city, as well as the most perfect structure yet erected to answer fully the special and different requirements for office and printing purposes. The Engineering Record will be pleased to see its friends at this new address.

The Utilization of Small Water Powers.

With the growth of electric power transmission has come an awakening to the importance of water privileges and one of the interesting results has been the rediscovery, as it were, of falls half forgotten and entirely passed by. In spite of this a great number of small streams remain undeveloped and offer excellent opportunities, not, to be sure, to the promoter who wishes to float bonds upon them, but to the actual investor and to the manufacturer who wishes power for his own proper uses. The bane of hydroelectric enterprises is "high finance," which saddles upon a proposed plant all the bonds that it can stagger under for years to come. A water power of one or a few hundred horsepower is too small to "finance," yet it often offers a capital chance for the bona-fide investor. Few people, even few engineers, realize fully what can be done with a comparatively small stream when intelligently developed. Other things being equal the smaller the stream for a given power, i. e., the higher the head, the better, since the cost of the hydraulic development is thereby greatly reduced. Also the cost of storage in considerable amount is then brought within reasonable bounds and adequate storage adds enormously to the practical value of the stream, as everybody knows. Few, however, appreciate the full importance of storage as applied to small streams, since on large streams generally developed at low head the practicable amount of storage is limited by the cost of the necessary riparian rights.

The ordinary stream is subject to enormous variations in flow, which cannot adequately be expressed in conventional averages. The spring floods are likely to be from twenty-five to fifty times the real minimum flow, and even more if one compares the maximum flood of a term of years with the minimum of the same period. The value of a stream for power purposes cannot be measured by the average flow since this is determined by unutilizable maxima. In a time of flood the flow is often so great as to cut down the working head, and is always greater than the capacity of any plant that can be profitably installed. Every stream has years of great and small flow scattered apparently by chance. A record of five or six years will catch the ordinary maxima and minima, but at least a quarter of a century is required to stand a reasonable chance of including extreme floods and extraordinary minima. Hence, so far as possible, the water should be stored. It is ordinary custom to store water during the night, thus holding double the normal flow for use during working hours. This is generally easy to accomplish at moderate cost. For instance, at 50 ft. working head a flow of 1,300 cu. ft. per minute will give about 100 h.-p. off the wheel shaft. If the power is used twelve hours per day one can store the other twelve hours' flow in a pond of a little less than 4.5 acres filled 5 ft. deep. This, however, is only the beginning of storage. The next step is so considerable a one that it is seldom undertaken, although it often would be very practicable. The ordinary continuous period of low water, at least in Eastern streams, is seldom more than 30 to 60 days and is preceded and followed by periods of considerably increased flow.

Now if sufficient storage capacity can be secured, say a hundred acres or so, this dry season can be tided over entirely and several times the normal low-water flow used steadily for twelve hours a day. Practically one is then able to use the stream on the basis of a point much nearer the average flow of the year than is possible with merely ordinary night storage, and to sell perhaps two or three times the amount of power that would otherwise be feasible without a stream reserve. One can, of course, go even further and store the entire yearly rainfall in an artificial lake, thus creating a useful water power from a stream entirely too small to consider except for storage. This has been done in a very few instances, and will be done more frequently as time goes on. The main point is that the usual small powers, apparently of little account, can, if the head be reasonably high, be developed by storage into excellent and reliable sources of revenue. The 100 h.-p. assumed at the start can be expanded not only into 200 h.-p. for twelve-hour use, but into 300 or 400 h.-p. and sometimes more. An electrical plant on which the demand for power fluctuates greatly through the day or night has its value determined very largely by the maximum load which it is able to carry over the peak and with good pond capacity this is measured by the capacity of the installation. Ordinarily the peak on a small plant will be three or four times the average daily power, so that if the plant just discussed is properly developed it may be able to carry a peak of 800 to 1,000 h.-p.

Lacking storage the peak must either stop at the normal flow or be eked out by auxiliary steam power. And the point needing emphasis is this, that in many cases, particularly on small streams, extensive storage is far cheaper than auxiliaries. One can hardly hope to install an auxiliary plant for less than $50 to $60 per electrical horsepower delivered, while in the case supposed a hundred acres of storage could generally be obtained, even if farm land had to be bought, for a sum far less than the first cost of the auxiliary it would replace. In these days of high voltage, a few miles of extra distance back in the hills involves no considerable extra cost, so that it would generally pay to develop well upstream where pond space would be available. There are many chances all through the hills of the country for just such small enterprises. In some cases the market will be found in lighting and power in towns a few miles distant, in others a single factory may find it profitable to utilize a stream for its own especial benefit. Many a small industry in which power is relatively a large item can in this way fall into an economy of production that is quite impossible if power has to be purchased or generated at the ordinary city rates. If engineers in drifting about the country on their various works would keep their eyes open for hydro-electric possibilities, they would find a surprising number of capital opportunities. The ordinary state surveys which purport to take account of the hydraulic resources of the country are very imperfect, since they notice only the more obvious falls and the larger streams. It is on the relatively small streams in a broken country that capital chances lie latent until some one with a keen eye brings them to light.

The Operation of Large Turbo-Units.

Few engineers who have not looked into the problem from the practical side realize the broad differences required in operating methods between very large and small or medium capacity power plants. The development of turbo units of 5,000 to 7,500 kw. normal rating demands a high degree of organization in the operating force of the plant which is made up of such large machines and their auxiliaries. In handling generators and turbines or direct-connected engine units of moderate capacity, the amount of money represented by each machine is not large enough, as a rule, to demand the elaborate precautions which one finds in the few great stations thus far built in 5,000-kw. units; and, again, the stoppage of a single machine in a station of a few thousand kilowatts rating does not mean anything like so much as it does in the case of a plant like the Long Island City station of the Pennsylvania or the Port Morris installation of the New York Central. There is no doubt that as the applications of electric power increase on a commercial scale, the use of very large units will become more common; and it is particularly important for prospective purchasers of such high-powered turbines to realize that the simpler and more easy-going methods of earlier plants must give way to an operating organization demanding real generalship in its handling, if the full reliability, flexibility and economy of the new and costly units are to be enjoyed.

In round numbers, a 5,000-kw. turbo-alternator represents an investment of from $150,000 to $200,000. The penalty of damaging such a machine by crude operating methods is evident on its face. Turbines of this capacity are designed so far as possible to take care of a long list of contingencies as to load and speed, and the governor mechanism may be counted upon to hold the machine within safe limits of turning over through all ordinary exigencies of starting, phasing in or shutting down. At the same time, definite responsibility and order of procedure must be insisted upon both on the switchboard gallery and on the floor of the turbine room itself. One or more sets of signals between the board and the floor are essential, and these must be reliable and simple, without the likelihood of their being confused in times of emergency. Hand signals are doubtless good enough for the working conditions of small plants, but in these very large stations lamp, bell or whistle signals, with supplementary telephone or speaking tube connections between floor and gallery are important features of good operation.

Anticipation of all probable contingencies is the main point at issue in planning for the skilled handling of large units. Under normal conditions the load upon the plant on the first five days of each week tends to follow substantially the same general variations from hour to hour, though the momentary fluctuations show less resemblance from day to day. Hence in routine service experience soon shows the hour each day at which a machine must be ready for service, and the probable duration of its service. Authority to cut in an additional unit may be granted to the floor engineer in charge of a given shift in case it becomes clear that the machines in service are in danger of being too heavily overloaded, but in any case the switchboard operators should be empowered to order in new machines if they are in practice held responsible for the continuity of the station output. The conditions in different plants vary considerably, and the exact measures of responsibility must be assigned with reference to the organization in force, but there should be no chance for things to go wrong because of divided authority. If the entire station is in charge of a single watch engineer, the decision may rest with him when to cut in or out machines, but a suitable organization will provide for fixed limits of continuous overload which shall not be exceeded without a second unit being thrown upon the bus-bars, in case one machine is handling the entire output of the station.

A clear-cut printed list of instructions as to the order of procedure and the signals to be used in bringing a turbine up to speed, synchronizing, cutting it out of service, transferring the load from one machine to another, handling exciters and auxiliaries, starting machines with the utmost possible speed in emergencies, and shutting down with all possible speed, is a valuable aid to operation in plants where such instructions can be properly applied and enforced. It ought to be unmistakable just what machines are designated by a given signal, and in this connection the use of audible signals can be very readily supplemented by lamp indications. Thus, the use of some form of engine telegraph, either with dial or lamp indications referring directly to the printed words "Start," "Stop," "Standby," etc., as in marine service, tends to reduce the chance of mistakes, as does the employment of an electric interlock in connection with the closing of the turbine oil switch which throws the machine upon the operating bus-bars. In some of the later installations it is impossible to complete the oil switch circuit unless the synchronizing plug is in its receptacle, and the circuit breakers cannot be closed unless the voltmeter plugs are in. The use of red and green pilot lamps to indicate the limit of speed conditions on the turbines, of similar lamps to show whether high tension switches are closed or open, with illuminated signs and special calls for emergency conditions, all tend toward reliable service. Foresight applied to minute details is the fundamental need of power plant organization in dealing with units of high capacity.

The Ambrose Channel at the Port of New York.

It is hardly likely that one American in a thousand, even in well-informed circles, appreciates what an important influence on commerce the Ambrose channel at the port of New York is likely to become. A few people have had a very hazy idea that an important channel was being dredged somewhere for some purpose connected with the improvement of the port, and a few engineers and contractors recall the work mainly on account of the troubles of those who originally agreed to carry out the undertaking for a sum about equal to that which an experienced dredging manager estimated as the cost of the necessary equipment to cut the channel in the time stipulated by the original specifications. As a matter of fact, it is the excavation of the Ambrose Channel that has made the "Lusitania" a practicable proposition, and without the work which the Corps of Engineers of the army has been urging forward with all practicable speed that great ship and the still larger vessels that will doubtless be constructed in the future would be hopeless failures. The relation of cause and effect in harbor work has rarely been shown more clearly than in the case of this channel and the famous liner that will shortly thread her way through it on her maiden voyage. The recent passage of the Cunarder "Caronia" through the new channel demonstrated its safety and great advantage over the old course, and showed that commerce will shortly be freed from its chief physical hindrance at the leading American port.

The problem in shipbuilding for the trans-Atlantic trade has been to secure maximum carrying capacity at minimum cost, or to increase the water-line length without an excessive addition to operating expenses. The high speeds attained by some liners cost so much that the vessels are generally understood to be operated at a loss, which is considered justifiable as an advertising proposition and is recouped by the profits of the slower vessels. If it were possible to build longer and deeper vessels, this high speed could be attained without such serious financial sacrifices, but it is manifestly no use to build a ship which cannot get into the harbor which is her destination on this side of the ocean. Up to the present time, therefore, ship-building has been checked, so far as fast liners were concerned, by the winding course and 30-ft. depth of the old Gedney Channel, and it was not until the Washington authorities gave an absolute promise of a better entrance to the harbor that the Cunard Company regarded the project for the "Lusitania" type of ship as practicable. The Ambrose Channel in its present incomplete condition will permit such vessels to come to their docks more easily than smaller liners have formerly made the trip over the old course, while the completed channel will admit vessels of 35-ft. draught at all stages of the tide and of lengths that would be unnavigable in the narrow, twisting Gedney Channel. It will thus be seen that the new channel does away with a physical restriction on the development of an important part of the port's commerce, and opens the way for progress in ship-building, the limits of which nobody can now foresee.

The channel which is making such a marked change in shipping and ship-building is intended to be 2,000 ft. wide and 40 ft. deep at low water eventually, although it will be a good many years before it is completed to these dimensions. At the present time it has a width of about 800 ft. and a minimum depth of 32 or 33 ft. at low water. This depth is not enough to make the channel free for the "Baltic," let alone the "Lusitania," at low tide, if they are fully loaded, but it will permit them to come up at any stage after the voyage over, when their coal supplies have been depleted. The new channel is about seven miles long. It begins about a mile and a quarter southwest of Coney Island, the famous amusement resort of New York, and extends in a generally southeasterly direction to deep water about half a mile north of the Gedney Channel. In the part already completed the channel has a depth of 45 ft. at the ocean entrance and come up for a mile and a half on the southerly side of the proposed 2,000-ft. channel; then crossing over gradually to the northerly side. The trial trip through the channel which was made by the "Caronia" indicates that the time of passage through it from the dock to deep water will be about half that required in going through the old course. The use of the new route for some time will be restricted to vessels of deep draft in order that interference with the work of improvement shall be as little as possible, and it is considered likely that for a time not many of the companies will care to follow the lead of the Cunard people and send their best ships over the new course. Even in its present incomplete state, however, the channel is a most instructive example of the assistance engineering can afford to water-borne commerce.

Riveted Connections in Steel Structural Work.

Notwithstanding the great developments made in steel structural work up to the present time there are a number of important details which cannot yet be satisfactorily designed in consequence of a lack of the requisite experimental data. The eye-bar, which was for many years of a more or less unknown, or at least speculative, character, may fairly be classed among those main details of a steel bridge structure which may be designed rationally and safely, if not with extreme accuracy. There has been accumulated a mass of results of tests of full-size bars of various classes of steel, and with such a variety of proportions as to form a fairly complete empirical basis of design for both large and small members. The design of an eye-bar head of such dimensions as to develop the full capacity of the body of the bar is no longer a matter of material uncertainty; the amount of experimental data now available is ample for its purpose. There are a number of other important structural details about which the same general observation may be made, but there are still others, including both riveted tension and compression connections, whose rational treatment in design is even now impracticable with substantial accuracy in consequence of a lack of sufficient experimental data.

Tests to failure of riveted joints in plates have been made in considerable number, especially for the purpose of determining the ultimate resistances of tension, shearing and bearing in riveted joints, but there have been comparatively few tests of either tensile or compressive connections between angles and plates or of the connections of angles with each other. There have been postulated certain obvious principles applicable to the design of all classes of riveted joints, such as that requiring the lines of stress in the members joined to pass through the centres of gravity of the groups of rivet holes employed in the connections. It has also been recognized that, in general, the best results in connecting angles to plates will be reached by using angle lugs so as to catch both legs of an angle member with the joint rivets. Furthermore, it has been recognized with equal clearness that the centre lines of stress of all the members meeting at a joint must intersect at one point. In applying these simple principles, however, there is such a paucity of experimental investigations in this class of riveted connections that it is in reality impossible to design such connections with that degree of accuracy which ought to characterize the best class of steel structural work at the present time. Again, the determination of the proper net section where rivet holes in different lines are staggered cannot be made in a rational manner, although an experienced engineer of good judgment may, and does, design his work so as to make this feature of his connections entirely safe. Also, if an angle lug is employed to catch that leg of the steel angle which stands at right angles to the connection plate, the designer is greatly in the dark as to the value of the lug as a detail of the connection. It is even unknown in some cases whether the latter will be improved by the lug or not, but that is practically about all that can be said with any degree of certainty.

Under such circumstances a paper on experimental investigation in this class of riveted details like that on "Tension Tests of Steel Angles, with Various Types of End Connections," read before the American Society for Testing Materials, at its recent convention at Atlantic City, by Prof. F. P. McKibben, cannot fail to be of substantial value. Although the number of tests is not very extended, they were made with full-size angles and there are enough of them to yield significant indications of practical importance.

While the results are not sufficiently extended to be conclusive, it appears that there may be a gain of ten to fifteen per cent. in efficiency by catching both legs of an angle, by the aid of a lug, in a tension connection when the greatest available net section is attained by a suitable staggering of the rivets. This gain appears to increase as the inequality in the lengths of angle legs diminishes. Indeed, that gain may disappear or even become negative, i. e., a loss, if the inequality in length of the angle legs becomes great. At first sight this may seem irrational, but it is what should be expected. When the leg perpendicular to the connecting plate becomes relatively short, as in a 6x4-in. angle, the rivet holes through it, required by the lug, may decrease the net section to such an extent as more than to compensate for the advantage of catching both legs. The tests of connections with that size of angles discloses precisely the results indicated, but with the difference in efficiency so small as to indicate that the 6x4-in. angle lies about at the limit. In other words, it may be advisable to use lugs with a less inequality of lengths of legs, but not when the inequality is more. This is an important practical indication, and its confirmation or modification should be sought by a continuation of tests of this class.

The investigations set forth in this paper also show clearly the importance of a well-considered disposition of the units at the connection. A proper staggering of them, especially with unequal legs, may materially increase the net section and thus enhance the efficiency of the connection. Finally, the results of Prof. McKibben's investigations indicate that it is more advantageous to use equal-legged angles and connecting lugs than those with unequal legs, either with or without lugs, as the efficiencies of the former are sensibly higher than those of the latter.

Few or no compressive tests of this class of connections have been made, in spite of the fact that they are much needed. Compressive connections are simpler in character than those in tension, as the complication of net sections does not exist, but the influence of bending is unknown in amount and can only be determined by actual tests.

Notes and Comments.

The Collapse of the Quebec Bridge on the afternoon of August 29th was a wholly unexpected occurrence, in spite of reports in the newspapers to a contrary effect. The cause of the collapse of the south anchor and cantilever arms is as much a mystery at this writing as ever, and while several explanations of it have been advanced they rest on such inadequate basis of fact as to be mere speculations which are worse than useless on account of their tendency to warp the judgment. The portion of the bridge that fell had been standing over a year; it had passed through the storms of the winter, and nobody had seen anything about it indicative of any serious condition. It is true that Mr. Theodore Cooper telegraphed on the day of the accident to the builders not to place any more load on the structure until it was looked over, but he authorizes the statement that this telegram meant nothing more than a warning that it was desirable to stop work until the superstructure had been critically examined. Neither he nor his inspector dreamed for a moment that there was any danger of immediate collapse. That the structure fell is, however, one of those grave facts which the engineer must face in all its stern reality. It seems almost hopeless to attempt to seek the cause of the accident in the twisted wreckage or to discover in the statements of those present at the time of the failure any clue to the reason for the catastrophe. Yet until that reason is definitely found engineering will be looked upon by the public with suspicion as daring too much for its resources and as too willing to run risks; the Philadelphia "Ledger" voiced this sentiment as follows: "The world's confidence in the skill and judgment of the engineering profession will be seriously shaken unless it can be shown that the accident was the consequence of unforeseen and unavoidable contingencies." Engineers themselves know full well that probably no structure ever received more careful attention in design, manufacture and erection than the Quebec bridge and they will be unwilling to attribute its collapse to defective proportions, inferior materials or faulty erection until definite proof is established to the contrary. Full details of the design and the method of erection have been published in a long series of articles in this journal, and elsewhere in this issue is a statement of all the facts that have been brought to light concerning the accident and the local conditions at the time it occurred. An examination into the accident is now being made by the Canadian authorities and it is to be hoped that this will be so thorough and complete that the cause of the collapse will be definitely revealed. Until it is known, the hazard of bridge-building on such a great scale will be something to consider with apprehension.

The Electrification of the Sacramento division of the Southern Pacific Ry. will be studied by Messrs. Frank J. Sprague, the eminent electrical engineer, and Mr. Allen H. Babcock, the company's electrical specialist. The latter has been investigating the electrification of the road from Rockline to Sparks for three years and the engineers of the large electrical manufacturing companies have made a special study of the subject. In many respects the problem of increasing the capacity of the division in question is one of the most important in the railroad world. It is over this division that the entire freight and passenger traffic of the transcontinental Union Pacific system, for Central California, is carried, and likewise the eastbound traffic. Some idea of the difficulties may be judged from the fact that in a distance of 83 miles there is a rise of nearly 7,000 ft., this section forming a part of the division on the west and east slopes respectively.

A Blow-off Tank Explosion in a St. Louis store resulted in the death of a power-plant operator, whose widow brought suit against the owners of the building for the death of her husband. The case has recently been decided, 103 S. W. Rep. 588, by St. Louis Court of Appeals in a decision of importance to consulting engineers. There were two blow-off tanks, sunk flush with the floor and separately connected with the boilers and the sewer. A 3-in. vapor pipe was provided for each tank, running up a few feet, then horizontally 12 ft., making three 45-deg. turns before rising to the roof. There was an upper and a lower valve in the pipe connecting the boilers and each tank, the lower valve being opened first and then the upper valve opened very slowly. The tank that exploded was within 18 in. of a boiler, so that to blow off the latter it was necessary for the operator to stand on the top of the tank, which was made of cast iron. While the operator was blowing off the boiler in the usual way this cast-iron top blew off and he was killed. The top was broken into pieces which were found to be honeycombed with holes. The owners of the building claimed that they were not liable for the results of the explosion, because they contracted with experienced and reputable people to furnish and install the machinery under the supervision of competent mechanical engineers also employed by them. They showed by witnesses that the blow-off tanks were of the standard type employed in the city and installed in the customary way, and consequently they claimed freedom from responsibility. The court has refused to uphold this contention and damages have been awarded against the owners of the building. It is laid down as good law as well as simple justice that the owners could not shift to the shoulders of another the responsibility for insuring the safety of the working place for their employees. The evidence showed conclusively that the lid was not subjected to any kind of test, and the court held that any ordinarily prudent person would have tested its soundness before putting it into use. This was the duty of the mechanical engineers engaged for the purpose of insuring the installation of a good plant, and these engineers were the owners' agents in the matter, so that their negligence was legally the negligence of the owners, for which the latter were liable in damages. This brings up a proposition which those who are struggling with proposed professional codes will do well to consider. According to the court's decision, "that the engineers were negligent in failing to test the head of the blow-off tank which blew up, does not admit of doubt." This being the case, should the engineers be considered responsible to the owners for the results of such negligence? According to the court's decision the accident was not due to an error in judgment, for which no professional man is properly held responsible in this way, but was caused by pure negligence, which is a very different matter. The question whether a professional man is liable to his client for damages in such a case is manifestly one that is open to considerable debate.

Private Library of Frank A. Randall Case No.

THE HYDRO-ELECTRIC DEVELOPMENT OF THE GREAT NORTHERN POWER CO.—PART I.

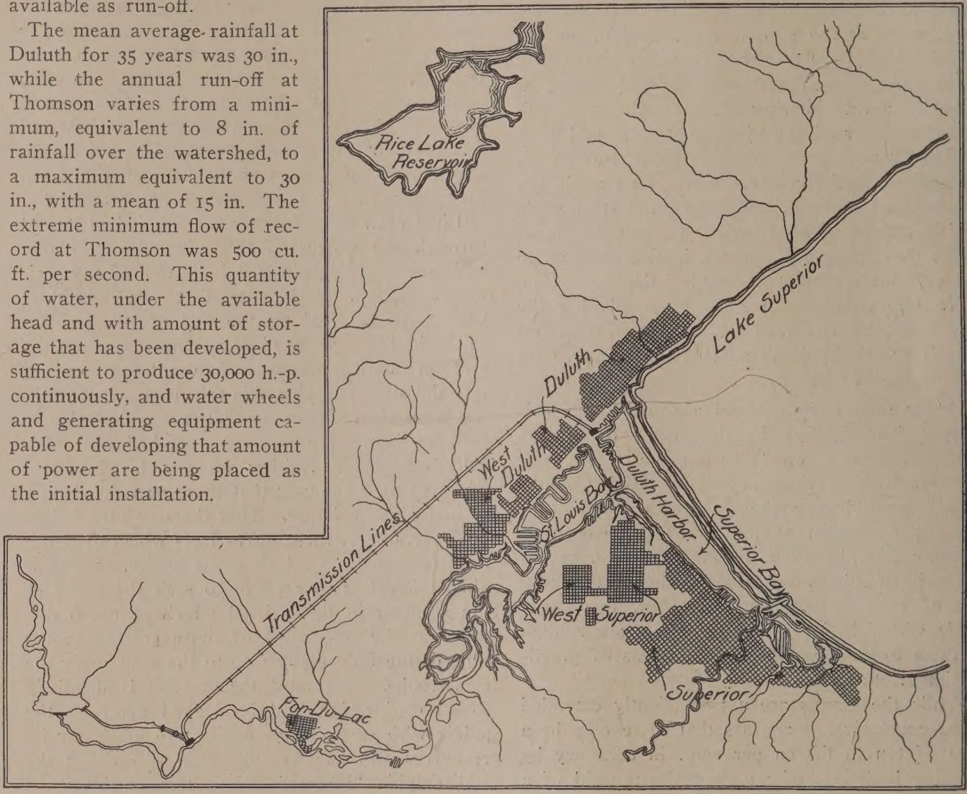
The hydro-electric development of the Great Northern Power Co. on the St. Louis River, near Duluth, Minn., is one of the most comprehensive hydraulic power projects that has been undertaken in this country. The important part of the hydraulic features of this development are practically completed, and that portion of the electrical generating equipment to be installed at first will soon be ready to operate. A service reservoir, with a capacity of 130,000,000 cu. ft., has been developed on the river at Thomson, 17 miles from Duluth. The river is by-passed from this reservoir to the power station, which is 2.8 miles down stream in a direct line. This by-pass consists of an open canal, 1⅔ miles long, that leads across a level plateau above the steep river valley, and of pipe lines extending from a forebay 3,500 ft. long, at the end of this canal, down the side of the river valley to the power station, which is at the edge of the river. The market for power generated in the station includes within easy transmission distances the cities of Duluth and Superior, the Mesaba, Vermillion and Gogebic Iron Ranges and other power consuming centers.

Water Power Available. The St. Louis River offers the only opportunity for any large, or important water-power developments within more than 100 miles of Duluth. The course of the stream is approximately a semi-circle, 150 miles in length, the headwaters of the main river being about 60 miles northeast of Duluth. The river flows west from its source, gradually changing in direction to south and finally to southeast near its mouth, which is 10 miles southwest of Duluth, in St. Louis Bay, an arm of Lake Superior. The Cloquet and the White Face Rivers are the principal tributaries of the St. Louis River. The headwaters of the former are about 15 miles southeast of the headwaters of the main river, the general course of the stream being toward the southwest for its entire length of approximately 75 miles. The Cloquet River passes to the north of Duluth, 15 miles from the city and joins the main river 30 miles from the mouth of the latter. The source of the White Face River is between the headwaters of the Cloquet and the St. Louis Rivers, the course of this stream, which is approximately 55 miles in length, being generally parallel to, and 15 miles north of the Cloquet River.

The sources of the three rivers are in the neighborhood of 1,150 ft. above Lake Superior, but only 585 ft. of this total fall of the main river occurs between the headwaters of the latter and a point 15 miles from its mouth. At this point there is a fall of about 45 ft., and in the next 4 miles a series of light rapids introduce a gradual fall. In the remaining 10 miles, from the upstream end of the service reservoir to the mouth of the river in St. Louis Bay, the total fall over a series of rapids is 465 ft., all of which will be utilized eventually by the Great Northern Power Co. Of this total fall, 378 ft. has been developed for the present hydro-electric station, and the remainder of the fall, which occurs below that station, will be utilized in a hydraulic development near the mouth of the river.

The total drainage area of the St. Louis River and its tributaries is about 3,700 square miles, consisting largely of connecting swamps, with alternate ridges covered with timber, dense undergrowth and small lakes. Although this territory has been made accessible recently by railroads from Duluth to the Mesaba Iron Range, which range is along the northern edge of the drainage area and about 60 miles from the city, it contains only a few settlers' clearings, county highways and logging railroads. Practically all of the pine that once covered the catchment area has been removed, but a dense forest of balsam, tamarack and hardwoods of various kinds still exists over most of the area. The surface of the latter consists of heavy glacial deposits of mixed gravel, sand and clay; these glacial deposits are underlaid on the headwaters of the river with hardpan, then for a width of 10 miles just above the present development, with slate, and from the end of this underlying slate to the mouth of the river, with brown sandstone. The catchment area is thus an excellent gathering ground for water, which is so gradually delivered into the streams that a relatively large percentage of the rainfall is available as run-off.

The mean average rainfall at Duluth for 35 years was 30 in., while the annual run-off at Thomson varies from a minimum, equivalent to 8 in. of rainfall over the watershed, to a maximum equivalent to 30 in., with a mean of 15 in. The extreme minimum flow of record at Thomson was 500 cu. ft. per second. This quantity of water, under the available head and with amount of storage that has been developed, is sufficient to produce 30,000 h.-p. continuously, and water wheels and generating equipment capable of developing that amount of power are being placed as the initial installation.



Map Showing Power Development, Duluth and Superior.

In order to provide for additional power installations, other storage reservoirs will be developed on the watershed. This reservoir development can be carried out very economically, as the swamps which make up a large proportion of the country at the headwaters of the three rivers offer unusually favorable opportunities to create immense storage reservoirs. The latter can be developed by simply placing dams across the small streams where these streams have broken through the glacial ridges. These dams for the most part need be only small structures, and it is estimated that the average cost of storage which will make 30 per cent. of the mean annual rainfall continuously availabe for power is approximately $1,500 per square-mile-foot.

Based on the development of storage areas which will render continuously availabe this 30 per cent. of the mean annual rainfall, another project, known as the Duluth Heights System, which is entirely distinct from the development at Thomson, is under consideration. This project contemplates the diversion of the headwaters of the St. Louis River and its tributaries through a series of canals and storage reservoirs to the crest of the steep hillside on which Duluth is built. This hillside reaches an elevation of over 800 ft. within a short distance from the water front of the city, and farther back forms the divide between the St. Louis River and the small streams flowing through the city into Lake Superior. A depression occurs in this divide through which the headwaters of the three rivers can be delivered into the central part of Duluth with a fall of 740 ft., or nearly twice as great as that available at the station on the St. Louis River. A reservoir which contains 17 square-mile-feet of storage has already been developed at Rice Lake in this depression, and for the time being will deliver water to the station at Thomson, but it is the controlling feature of the diverting scheme.

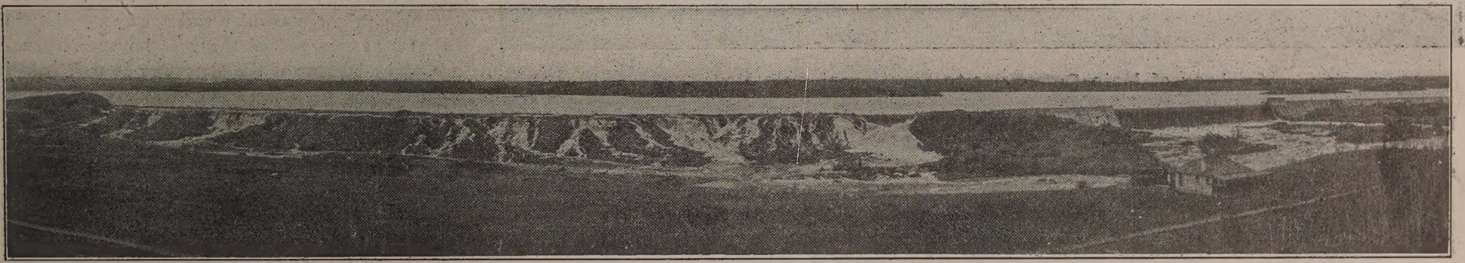
In case this scheme is carried out, 2,375 square miles of catchment area will still be tributary to the present station. If sufficient storage capacity is provided to render available 30 per cent. of the rainfall on this area, or one-half the total run-off, 80,000 electrical horse power can be developed in this station, based on a 42 per cent. load factor. At the same time 10,000 electrical horsepower can be developed in a station in Duluth operating on the water diverted from the three rivers under the available head of 740 ft. made possible by this diversion, and based on the same amount of storage and the same load factor as is contemplated for the station at Thomson. In addition to these two developments, 15,000 h. p. can be rendered available by the construction of a dam and power station to utilize the 70 ft. of fall in the river below the existing station.

Service Reservoir. The principal function of the service reservoir at Thomson is to conserve and regulate the flow equalized by the storage reservoirs so the variable demands for power each day may be met without loss of water. The capacity of this reservoir between the crest of an overflow spillway and the lowest depth to which water may be drawn into the canal leading from it to the power station, in a total draft of 12 ft., is 130,000,000 cu. ft., which is sufficient to accomplish this purpose of conservation and regulation. This reservoir is also capable of furnishing water to operate the ultimate installation of 80,000 electrical horse-power at 50 per cent. load factor for 23 hr. without supply from the river. Furthermore, it will permit sufficient time to obtain a supply from the storage reservoirs in case of an emergency, without interruption to the service.

The service reservoir is about 1½ miles long and ½ mile wide, its long axis being nearly at right angles to the channel of the river. The latter in this vicinity cuts across a series of ridges of dense slate rock, which rise 10 to 60 ft. above the general level of the country, one of these ridges forming the downstream side of the reservoir. A main dam was built across the channel which the river had cut through this rock ridge and a series of low dams were erected to close the breaks in the latter.

The main dam has a total length of 1,120 ft., and is a gravity-section concrete structure. The spillway section of the dam is 40 ft. high from the bottom of the foundations to the crest, 42 ft. wide at the base and 365 ft. long. At one end of this section three sluice-ways are extended through the dam near the bottom so the reservoir may be drawn down through them. Each of these openings is controlled by a 7x9-ft. sluice gate. These gates have non-rising stems which pass through operating stands in a concrete gate house built on top of the dam. The stands are geared so they may be operated by hand.

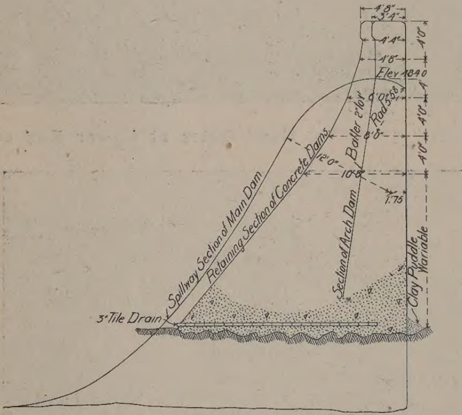
A retaining section of the dam, 609 ft. long, extends from the gate house to a high point on the rock ridge, and a second retaining section, 146 ft. long, extends from the opposite end of the spillway of the dam to a spillway that has been formed by cutting down the rock ridge. The crest of the spillway of the dam is at Elevation 484, as referred to the level of Lake Superior; the top of the remainder of this dam and of the smaller dams around the reservoir are at Elevation 490, except two earth dams, the crests of which are at Elevation 492. The spillway formed on the rock ridge has a length of 1,000 ft., and is 18 in. higher than the crest of the main dam, that is, at Elevation 485.5. An extreme flood of 60,000 cu. ft. per second can be passed over the spillway of the main dam and this rock spillway without overtopping any of the retaining dams. This is in excess of any floods that may reasonably be anticipated, however, as the maximum flood of record is 52,000 cu. ft. per second.



Main Dam and Spillway over Rock Ledge at Service Reservoir.

Seven of the smaller dams, of which eleven were built, are gravity-section concrete structures. Two low earth dams, with paved slopes on the water side, one rock-fill dam having a concrete core wall, and one arch concrete dam make up the remainder. The rock-fill dam was built with the material removed to construct the spillway over the rock ledge. The core wall of this dam rises to the same height as the retaining dams. The arch concrete dam was built across a deep, narrow opening in the rock ridge in order to save concrete as compared with a gravity-section dam. It has a clear span of 60 ft. at the crest, is 60 ft high at the middle, and is built as an arc of a circle with a 100-ft. radius.

Upper Head Gates on Canal. The outlet from the service reservoirs into the canal connecting the latter and the pipe lines leading to the power station, is through submerged openings in a concrete retaining dam at the end of the reservoir closest to the station. The design of the outlet is such that the water will be drawn from the bottom of the reservoir in a manner that will keep the velocity of approach low, so that very little ice or floating matter is expected to pass through the submerged openings and enter the canal. The substructure for a gate house, 35x83 ft. in plan, is built into the dam and contains the outlet openings, of which there are eight, each controlled by a 6x9-ft. sluice gate. These gates are each in a well on the reservoir side of the substructure, the water entering these wells through a heavy timber rack. This rack, which is expected to intercept floating debris and ice, consists of 3-in. planks, set on edge and spaced 10 in. apart on centers. These planks are supported by steel frames arranged so sectional iron grate bars of any spacing that may be found desirable may be installed later in place of them. The rack is outside of the gate house superstructure, a platform walk being provided along the top of it to facilitate the removal of debris intercepted by it. Three of the eight sluice gates are now installed, and the remaining five openings are closed with stop logs placed in the channels provided in the concrete on both sides of the gates until such time as more gates are required. These gates have rising stems, each of which passes through a ball-bearing operating stand in the gate house. These stands are arranged so the gates may be operated by induction motors, which will be started and stopped automatically by a float in the well connected with the canal; the motors may also be operated by switches in the gate house; or the gates may be opened and closed by hand.



Sections of Concrete Dams.

Canal. The canal has a total length of 1¾ miles between these headgates and the forebay and is entirely in excavation. It has been built to supply water to operate the ultimate installation of 80,000 h.p. The first mile of it from the service reservoir is through an earth cut, which crosses occasional rock ridges. This length of the canal was designed to be 36 ft. wide on the bottom, 15 ft. deep and to have side slopes 2 on 1. The grade of the bottom is 0.00015 and the coefficient of roughness of the wetted perimeter is assumed to be 0.03. The maximum velocity of flow through the earth section when the canal is running to its full capacity will be about 2.8 ft. per second and the discharge 2,900 cu. ft. a second. The excavation was largely made with a steam shovel, and in order to reduce the cost of this work, the cut was made 66 ft. wide in the bottom and has steeper side slopes than specified by the design. It is expected these slopes will flatten out later, probably to an excess of 2 to 1. The remainder of the canal, a length of about 3,500 ft., has been excavated through slate rock with occasional short sections of earth reaching nearly to the bottom in some cases. The cut through the rock was designed to have as a minimum cross-section a rectangle 36 ft. wide and 15 ft. deep. As actually constructed the section is somewhat irregular, but in no place is the cross sectional area less than 450 sq. ft. The grade of the canal in this rock section is 0.0015, and the coefficient of roughness 0.033. The maximum velocity through this section will be about 7.5 ft. per second, with a discharge of 2,900 cu. ft. per second, the same as for the earth section.

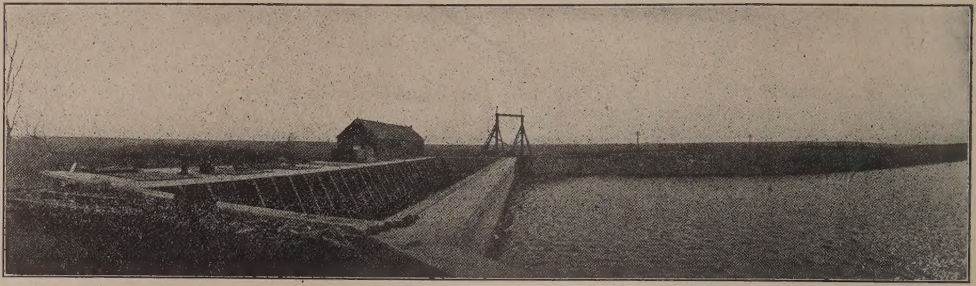
The canal crosses one of the tracks of the Northern Pacific Ry. about ½ mile from the upper head gates. According to the original location the canal and the railroad formed an acute angle at this crossing, but it became necessary to introduce a reverse curve in the canal in order that the railroad might be crosssd more nearly at right angles. The railroad crosses the canal on a 70-ft. span deck plate-girder bridge carried by concrete abutments, which are built for a double-track bridge. The sides of the canal are lined with concrete in the form of warped surfaces in both directions from the abutments in order to bring the side slopes of 2 to 1 in the earth section to the vertical at the abutments, and to prevent wash at the sharp turns.

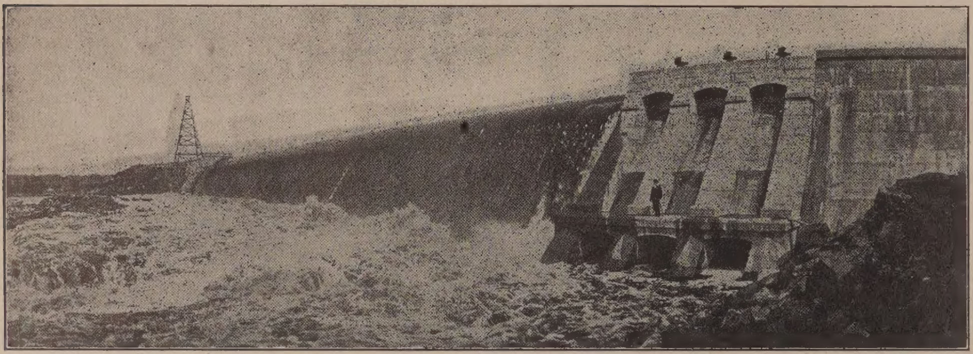
A concrete wasteway, 200 ft. long, is built in the right-hand side of the canal just below the railroad crossing, where water can be discharged over it into a ravine. This wasteway has a concrete lining, 18 in. thick, and is sloped 2 to 1 on the canal side, a discharge apron of paving stones set in cement mortar being placed on the hillside below it. The crest of the wasteway is at an elevation which will prevent the overtopping of the embankment that forms one side of the forebay at the lower end of the canal. The latter being all in cut is protected against such difficulty, as well as against breaks.

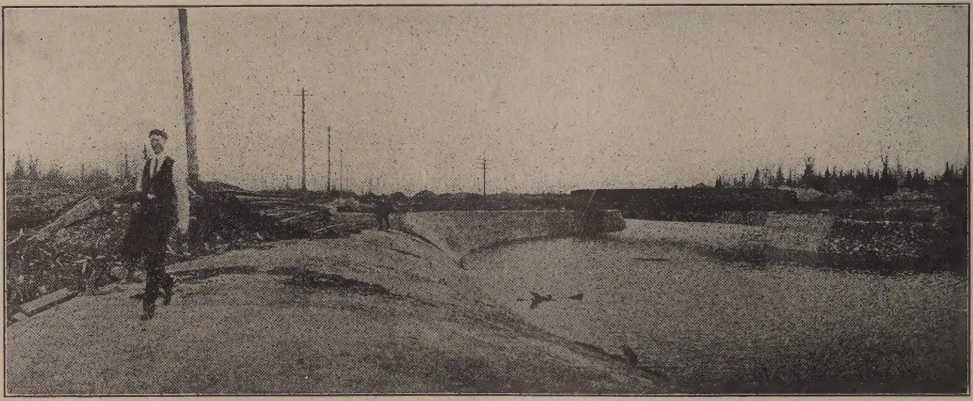
Forebay. The 40-acre forebay at the lower end of the canal is included to provide for sudden fluctuation of station load without necessitating continual changing of the upper head gates on the canal. The forebay also acts as a settling reservoir which prevents grit being carried to the water wheels. It has an average depth varying from 25 to 30 ft., and an available capacity of approximately 15,000,000 cu. ft.

The forebay is formed on the side of the hill by an embankment 3,500 ft. long and with an average height of 30 ft. This embankment was designed for a top width of 20 ft., with a slope of 2½ to 1 on the water side, paved to a depth of 3 ft. with rock from the canal excavation, and a slope of 1½ to 1 on the outer side. As built the embankment has greater dimensions and contains more material than called for in the design, spoil from the canal excavation which was unsuited for the embankment proper having been wasted on its outer slope. The inner slope is also somewhat steeper than specified and is covered with rock from the canal excavation which was thrown on it roughly. About 85,000 cu. yd. of treacherous material was removed from the site of the embankment in order to reach a hardpan foundation. A timber core wall, consisting of a double-lap row of 2-in. planks, was built up on the center line of the embankment, extending from the hardpan nearly to the top of the latter. Material was dumped into the embankment from cars on a trestle, and was sprinkled as it was placed. The bottom of the forebay consists of a 3 to 10-ft. layer of good clay which forms a water seal with the core of the embankment. The latter has been finished nearly two years, during which time it has consolidated and retains the water in the forebay without any leakage.

Ice Conditions. Ice conditions on the river have been carefully observed and provisions have been made in all open water-ways to prevent interruption to the operation of the power station by ice in any form. It is believed that surface and needle ice will neither one be specially troublesome. A water-power development at the 45-ft. fall which is 5 miles upstream from the service reservoir has operated for 7 years without interruption by ice, although no provision to avoid difficulty from this source has been made and the natural conditions are much less favorable than at Thomson. Very little needle ice has been observed in the river at the site of the service reservoir, because the stream above this point freezes over in November, the ice remaining intact and covered with snow during the entire winter. The water is thus protected from direct contact with the cold air and the formation of needle ice is reduced to a minimum. Furthermore, the river enters the reservoir something over a mile from the upper head gates on the canal, so any needle ice that may reach the reservoir will probably be dissipated in passing this distance. The ice sheet formed in the river has thus far melted in place in the spring, so very little floating ice has been observed in the reservoir.


Head Gates at Lower End of Forebay during Construction.


Spillway of Main Dam Prior to Erection of Gate House.


Construction View of the Wasteway on the Canal.

The expectation is that ice will form over the water in the earth section of the canal, in which the velocities are low, during such time as only enough water is supplied to operate 30,000 h. p., and probably until nearly the ultimate of 80,000 h. p. has been installed. It may also form over the water in the rock section of the canal at the start, but the water in this section is nearly certain to be more or less open when the full installation is in service. The period of time that the water will be exposed in the open sections of the canal will be so short, and the depth and volume of water in these sections so great that little, or no needle ice should be formed while the water is passing these sections. The water in the forebay will be frozen over and will afford the same protection against needle ice entering the pipe lines that is afforded to the canal by the service reservoir.

Lower Headgates. The outlet from the forebay into the pipe lines is through headgates at the downstream end of the forebay. A heavily reinforced concrete substructure for a gate house, 40x145 ft. in plan, is built across the end of the forebay, the reinforced-concrete bottom of this structure being on hardpan at the same elevation as the bottom of the forebay at the approach to it. A concrete cut-off wall extends 10 ft. into the hardpan on which the bottom of the structure rests, and the full length of the latter. The bottom also extends into clay puddle at the front of the structure, the junction being protected by rock paving. Concrete wing walls are built from each end of the gate house into the adjoining banks in such manner as to form a perfectly safe seal that prevents water from escaping around the ends of the structure.

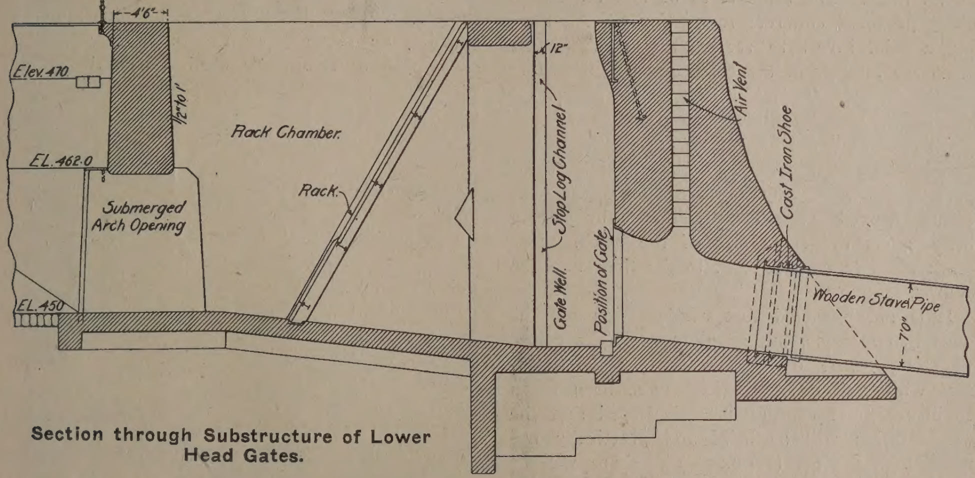
The upstream side of the gate house substructure is a heavy curtain wall containing eight submerged arch openings through which the water passes to enter a rectangular chamber for racks that intercept any floating debris that may reach this chamber. These racks consist of steel bars spaced close together and assembled in removable sections. In the rear of the rack chamber, which is within the lines of the gate house that is to be erected on this substructure, are eight wells, each 15x20 ft. in plan. The openings leading to the pipe lines are each controlled by a 6x9-ft. sluice gate, one of which is to be placed in each gate well. These gates have non-rising stems which pass through ball-bearing operating stands on the floor of the gate house. The pitch of the screws on these stems was made high so the gates can be closed very rapidly by hand. Provision has also been made so the gates may be operated by motors, and as it will require considerable time to open the latter by hand, the motors will probably be installed and will be arranged so they may be controlled directly from the switchboard in the power station in case of an emergency.

Thus far only three of the eight wells are provided with gates, the others being closed with stop logs until such time as they are needed. Grooves are built into the forward end of each well so stop logs may be inserted on that side of each gate to facilitate repairs to the latter.

The ice and debris which collect in front of the curtain wall can be flushed out of the forebay through a rectangular sluice way opening in the wall at one end of the gate house substructure. The bottom of the sluiceway is well below the quiescent water level in the forebay, and a rising gate is provided in the sluiceway so ice and other debris may be flushed over this gate at different stages of water. A wooden sluice box on a trestle extends out on the hill side for a short distance to a point where a drop of about 20 ft. is secured. The flow from the sluice drops on a wooden apron and is carried away from the works at the end of the forebay.

Pipe Lines. Three 7-ft pipe lines have been laid in a trench from the lower head gates to the power station, a distance of 5,000 ft., and will be covered with 2 ft. of earth. Wooden-stave pipe was used for the first 4,000 ft. of these lines from the head gates, in which distance the fall is 150 ft., and riveted-steel pipe in the remaining 1,000 ft., in which the total fall is 228 ft. The grade on which the wooden pipe is laid is continually descending and at the flattest point is sufficient to maintain velocities that will prevent any tendency toward a collection of air in the pipes. It was determined that the economical point to end the stave pipe and begin the steel pipe was where the pressure was equivalent to 150 ft. of head. The cost of wooden-stave pipe up to this head was estimated to be less than that of steel pipe, owing to the fact that the bands which take the strain can be placed in such manner as to obtain the most efficient distribution of metal, which variations would not be practicable with steel pipe. It is expected that the steel bands may rust out in 20 to 30 years, but in such event, they can be replaced one at a time in a manner that will avoid interference with the operation of the pipe lines. It is believed that the staves will last indefinitely, as they will be kept saturated by water under pressure.

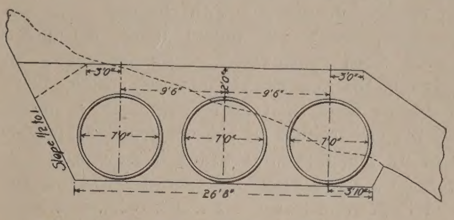
The staves are of California redwood, which was almost perfect lumber, without knots or flaws. They are each 3½ in. thick and were cut accurately to a template with arcs and radial sides of a 7-ft. circle. The bands are made of round ¾-in. steel, the shoes and turnbuckles used to join them being malleable cast-iron. The bands and shoes were dipped in hot asphalt before being placed and were spaced according to the pressure in the line. Leakage between the butt ends of the staves is prevented by inserting plates of metal, which were placed in saw cuts and then driven to a tight fit. The wooden stave pipes, which were built by the Excelsior Wooden Stave Pipe Co., of Lynchburg, Va., proved perfectly satisfactory when tested.



Section through Substructure of Lower Head Gates.

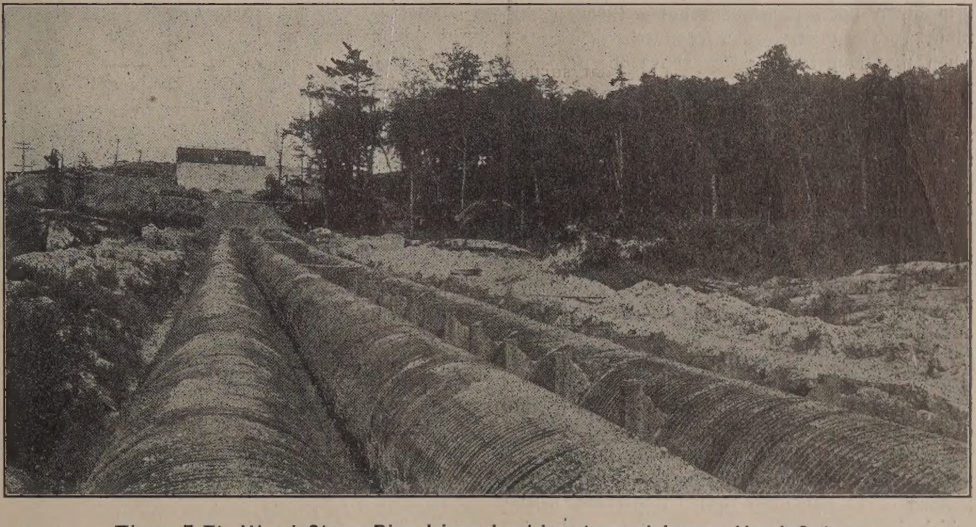
The joint between the stave and the steel sections of each pipe line was made by inserting the stave pipe into a cast-steel bell on the steel pipe and calking the joint with oakum and lead. A similar joint was also made at the end of each wooden-stave pipe at the gate house, where a cast-iron bell flange for each pipe was set in the concrete.

The 1,000 ft. of steel pipe at the lower end of each 7-ft. pipe line is built up of steel plates. The longitudinal seams are triple-riveted, with double-butt straps and the circular seams are double-riveted, with double-butt straps. The pipe was designed with a factor of safety in excess of three, an additional 1-16 in. of metal being added for rust. The pipe was dipped in hot asphalt and is laid in a trench and backfilled the same as the stave pipe. The grade at which the steel pipes are laid is all in the direction of the power house, the fall being about 228 ft. in the 1,000 ft. of pipe. The lower ends of the pipes are anchored securely in concrete and are tied into the brown sandstone ledge under the foundations of the power station with railroad rails. No expansion joints were placed in the steel pipe, as it is assumed the expansion caused by the variation between the limits of temperature during operation would be taken up by the elasticity of the metal. Reaction to insure this occurrence is obtained by angles which are riveted to the pipe at short intervals and flare out into the backfilling. Care was also taken to make the last joint in the steel pipe when the temperature was about the same as the average temperature of the water. The pipe was built and placed by the Riter-Conley Mfg. Co., of Pittsburg.



Trench for Three 7-Foot Pipe Lines.

Manholes are provided at suitable intervals along each pipe line and two automatic air valves are placed in each pipe to prevent any tendency toward the formation of a vacuum due to a very sudden acceleration in the flow of water. These air vents are at changes in the grade of the pipe lines, and an open vent is placed on each pipe inside the gate house at the upper end of the pipe lines. The outside vents are protected from freezing to insure their action in cold weather.



Three 7-Ft. Wood Stave Pipe Lines Looking toward Lower Head Gates.

The velocity of flow in each of the 7-ft. pipe lines when delivered 335 cu. ft. of water per second, which is equivalent to 10,000 electrical horse power at the generator, will be 9 ft. per second, and the maximum velocity will be about 11 ft. per second. The average velocity, due to a 50 per cent. load factor, will be about 5 ft. per second. The average friction loss in the entire 5,000 ft. of stave and steel pipe lines will be approximately equivalent to 10 ft. of head.

Stand Pipe on Pipe Lines.—Each of the three 7-ft. steel pipe lines from the forebay to the power station is connected to a large steel standpipe erected on a tower which spans them at a point about 500 ft. back of the station and 155 ft. above the water level in the river. A cross receiver, 8 ft. in diameter and 36 ft. long, is placed horizontally over the pipes and between the legs of the standpipe tower. Each pipe has a short 60-in. riser connecting it with this receiver through a 60-in. valve. A 6-ft. riser extends from this receiver to the standpipe tank, which is 30 ft. in diameter and 69 ft. high. The top of this tank is 235 ft. above the footings for the standpipe tower and 495 ft. above the level of Lake Superior, while the water surface in the forebay will be 472 ft. above that level. This standpipe was built and erected by the Chicago Bridge & Iron Works.

The standpipe has several important functions in connection with the operation of the water wheels in the station. First, it will relieve the pipe lines of excessive pressures due to a sudden closing of the gates in the water wheels following a quick drop in the demand for power. Second, it will also maintain pressures and speed regulation in the station when sudden demands are made for water; the 30-ft. standpipe has sufficient capacity between Elevations 426 and 472 to supply enough water to the wheels to meet a sudden demand for power up to 15,000 h.-p. and to maintain the head required for good regulation by governors on the water wheels until the water in the pipe lines back to the forebay is given an opportunity to accelerate sufficiently to meet the added demand for power. Third, the top of the standpipe being well above the water level in the forebay, enough back pressure will be exerted on the pipe lines to prevent any tendency toward the formation of vacuum at the changes of grade where the air valves are placed. Fourth, the cross receiver and standpipe will permit a flow to be maintained continuously in all the pipe lines during freezing weather, even though all of the water wheels in the power station are not in service; the friction losses in the pipe lines can also be reduced when the station is running at part load by continuing all the pipes in operation through the cross receiver. And, lastly, the standpipe provides a vent for the escape of any air bubbles or entrained air that might otherwise tend to produce water hammer in the casing of the water wheels. The principal value of the standpipe, however, is the saving it will effect in the water that would otherwise be wasted through relief valves which are provided at the water wheels in order to secure proper speed regulation and to avoid dangerous excess pressures in the water system.

The cross receiver and the base of the four legs of the standpipe tower are on heavy concrete footings. The 60-in. connections for four pipe lines are imbedded in the concrete under the receiver, so the fourth pipe line can be attached when it is laid. The four additional pipes, which are contemplated when the ultimate installation is completed, will be connected with an extension of the cross receiver.

The standpipe tank is of standard design with a hemispherical bottom. The 6-ft. riser has a slip expansion joint at the bottom of the tank, but it is to be so protected as to prevent the water from freezing. A frost box, 9.5 ft. in diameter, will be built around the riser, and the tank will also be lagged, so during excessively low temperatures warm air may be passed through the space enclosed by the frost box and lagging.

(To be continued.)

Glass Blocks for Tunnel Lining.

The Pennsylvania R. R. has for some time been seeking a thoroughly satisfactory lining for the passenger tunnels leading under the tracks from the stations to the platforms on the opposite side, and though repressed and waterproof brisk, glazed and glass tile, and enamel brick have been used, none of them have been free from objections. On the other hand, some of them possess quite marked merits as a material for a finished lining for tunnel work. Some of the materials mentioned are subject to cracking on account of changes of temperature, others chip and spall off under the action of frost, and a number of them being non-porous allow the moisture which accumulates on their surface to drip down upon passengers going through the tunnels. The main trouble occurs in the winter when the temperature rises above the freezing point after several days or weeks of severe freezing weather. The bench walls become chilled and remain so for about 24 hr. after a change to warmer weather. At such times the condensation upon the surface is heaviest and the spalling off and crazing is most severe.

After a consideration of the materials mentioned it was decided to try something new, and accordingly specially designed glass block will be used in the passenger tunnel now building at Edgewood, a suburb of Pittsburg. Certain features have been embodied in the design of the new material, which it is hoped, will result in doing away with the objections found in the other linings.

The defects of all of the materials thus far experimented with can easily be seen by anyone making a casual inspection. Repressed brick, which is usually of a porous nature, absorbs moisture condensed on its face, and owing to its damp condition becomes a lodging place for dirt and grime and in a short time presents a very unsightly apeparance. Waterproof brick, on the contrary, does not have the most objectionable feature of porous repressed brick but does condense the moisture permitting it to run down the face of the lining to the floor. The experience with enamelled brick has been very extensive, almost every make and size having been used. Some of these have been found to craze and spall off under the action of frost, while those not affected in this manner nevertheless condense the moisture, the same objection mentioned in connection with waterproof brick.

Glazed tile will absorb moisture, and in zero weather this moisture freezes and spalls off the glazed face together a portion of the tile itself. These unglazed portions soon become black and the whole lining assumes an unsightly appearance. Glass tile has been found to be nearly impossible to bond to the plaster lining necessary in tunnel construction, and the moisture eventually gets in between the tile and the plaster and in freezing weather forces off the entire tile face.

It is recognized that a lining for this purpose must meet rather severe conditions owing to its exposure to large temperature variations, and the fact that the temperature of the lining will not change concurrently with changes in the atmosphere, due to the tunnel being surrounded by the earth embankment of the railroad. In designing the new blocks, therefore, these severe conditions have been held continually in mind, and the elaborations of the constructions is justified by the difficulties which it is expected to overcome. The glass brick which will be put in at Edgewood measure 2 x 4 x 8 in., and have a hollow center, the wall forming the face being ⅝ in. thick. The brick is to be laid on a specially prepared concrete foundation offsett, having a 2-in. invert to receive any condensation from the interior of the brick and conduct same to the sewer. In addition to this precaution the hollow interior allows the brick to be well ventilated and the passage of air through it will insure almost as rapid a change of the temperature of the lining as of the atmosphere itself. The ventilation is provided for by placing brass grills the same size of the brick, every tenth brick in courses next to the floor and the ceiling.

It is not expected that condensation will be entirely overcome, but as glass rapidly assumes the temperature of the air it comes in contact with, and as precautions have been taken to insure good ventilation, it is hoped that the condensation will be brief and practically unnoticed. As glass is non-porous there will be no trouble with the face of the work spalling off, due to frost, and no trouble is apprehended from crazing, as experience has shown that this does not occur where glass is used alone. The glass naturally has the same advantages as enamelled brick and glazed tile in giving a smooth, pleasing finish and a surface that does not afford lodgment for dirt.

Mr. W. C. Richey, master carpenter, Pittsburg, has charge of the work.

Oiling Roads as a method of laying dust has aroused considerable criticism in some quarters, and for this reason some statements concerning a piece of work of this sort in Morristown, N. J., recently made by Mr. Wm. S. Bacot, one of the leading road engineers of this country, deserves considerable attention. Mr. Bacot states that a stretch of about 2 miles in Morristown has been oiled with an odorless compound unknown to him, but the results are so satisfactory in laying dust that he considers the experiment an important one. Prior to the oiling of the road, the large number of automobiles using it made the dust in the vicinity of the road so heavy that, in his opinion, the oil treatemnt would be advisable even if the roads wore out faster on account of its use. Fortunately the wear on the road does not seem to be at all comparable in amount with that on other roads in the vicinity, supporting an equal travel, but sprinkled with water regularly. Mr. Bacot states that he has observed the effect of oiling a hard road free from dust to be more lasting than is the case with roads having a surface of considerable loose material, which required frequent applications of the oil to produce the same results. In this connection reference may be made to the report of a commission appointed by the Minister of Public Works of France, noticed in this journal four weeks ago, expressing the same opinion.

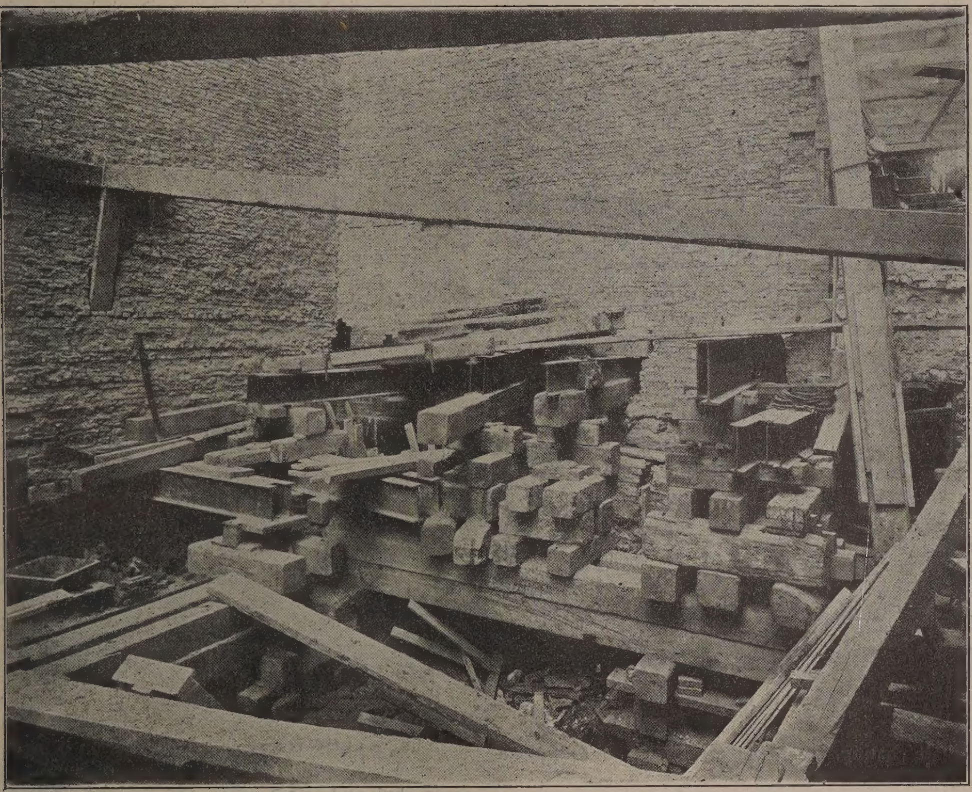
A Combined Underpinning and Sheeting Job.

A new six-story steel cage bank building on the southwest corner of Murray St. and Broadway, New York, is enclosed on two sides by an L-shaped seven-story and basement office building, with the floor beams supported without columns in the thick brick wall, having their foundations seated about 12 ft. below the curb on coarse sharp sand. The adjacent walls of both buildings are throughout their entire length in contact upon the party lines and recesses had to be cut in the face of the long wall of the old building to clear the steel columns of the new building. The vaults for the new building extend about 15 ft. under the sidewalk in both streets and are enclosed on the outer sides by heavy brick retaining walls about 24 ft. high with their foundations at the same level as those of the other footings, above water level on the dense sand about 24 ft. below the curb. After the demolition of the old building the first work was the underpinning of the adjacent building and the sheeting and bracing of the outer side of the excavation to retain the earth under the roadway. The contract for both sheeting and underpinning and for the construction of a sidewalk bridge and overhead platform on two faces of the lot was awarded to Miller, Daybill & Co., Brooklyn, and is now nearing successful completion.

Six equidistant pits about 6 ft. square in a line parallel to the long wall of the adjacent building and about 10 ft. distant from it were sheeted down to a depth of 24½ ft., about 6 in. below sub-grade of the new cellar, and in each of them there was built a timber crib 5 ft. square and about 15 ft. high. Four lines of 12x12-in. timber breaking joints, were supported on the tops of the cribs forming a continuous 48x48-in. longitudinal girder about 125 ft. long parallel with Murray St. At the end farthest from Broadway this girder supported one end of a similar 48x48-in. transverse girder, about 25 ft. long with the opposite end carried on a similar crib pier. The two girders thus formed a continuous L-shaped footing extending around two sides of the lot to receive the ends of the needle beams used for supporting the walls of the adjacent building while they were underpinned.

The basement of that part of the adjacent building which fronted on Broadway was occupied and therefore inaccessible to the contractor who was obliged to do his work without interfering with it. He therefore cut holes about 6 ft. apart on centers through the footing of the wall below the level of the basement floor for the needle beams and from these holes excavated short horizontal transverse drifts about 15 ft. long under the basement floor. From the extremities of these drifts a tunnel about 5 ft. deep and 4 ft. wide was driven the full length of the wall, 135 ft., and on the bottom of it were laid four tiers of 12x12-in. timbers, breaking joints and making a 48x48-in. continuous sill comparable with the girder on the opposite side of the wall and intended to receive the inner ends of the needle beams. A set of three 15-in. I-beams about 25 ft. long was inserted in each of the holes with the ends resting on the 48x48-in. girders and sills in the old building and on short cribbing piers on top of the 48x48-in. girder in the lot. A 15x¾x20-in. horizontal bearing plate was laid on the top flanges of the group of girders in the plane of the wall and a corresponding piece of plank 3 in. thick long leaf yellow pine covered with cement mortar was set on top of it filling the space between the top of the beam and the upper part of the hole in the brick work. As soon as the cement commenced to set wedges were driven between the steel plate and wooden plank and forced the latter up to make solid bearing against the old brick work when the remaining cavities between the wedges were filled with grout and the whole allowed to set and form tight packing between the needle girder and the wall. A thick horizontal cast-steel plate engaging a special 4-in. 24-ton jack screw with bevelled threads was set on a pair of beams built into the crib-work under the outer end of the needle beam with the upper end of the jack-screw bearing against a cap plate engaging the lower flanges of the I-beam. The jack screws under the needle beams were simultaneously operated until their supports were thoroughly compressed and settled and the full weight of the wall was taken by the needle beams giving them a deflection of about ¼ in. at the center point.

Similar needle beams under the 40-ft. long wall parallel to Broadway were allowed to penetrate the unoccupied basement in that wing of the old building and were therefore supported at their outer ends on higher timber cribs built up from the top of the 48x48-in. transverse girder. As the width of this wing of the building is only 15 ft. from out to out, the needle beams were carried entirely across it and their inner ends projected through holes cut for that purpose in the opposite wall and were seated on the brick work there thus making the wall and its footings serve as a sill distributing the load from the needle beams, instead of preparing a special sill as in the other wing of the building.



Needlebeams under Murray Street Building.

At an angle formed by the intersection of the walls of the old building the corner pier of the brick work was carried by a needle beam making an angle of 45 deg. with each wall and intersecting both just beyond their point of intersection so as to secure full bearings on both. This needle beam consisted of two 15-in. I-beams 20 ft. long seated on one 12x12-in. timber 25 ft. long that was supported at both ends on the adjacent needle beams carrying the intermediate portions of the wall as already described.

The wall parallel with Broadway terminates at Murray St. with a 3x4-ft. brick pier having an estimated load of 100 tons. On account of the small area of the pier it was underpinned in sections and care was taken to cut away only a small portion of the brick work and immediately support it on a part of the sectional underpinning before reducing the area of the pier to any great degree. A recess 6 in. deep and 24 in. high was first cut on the outer face of the pier and in it was placed 2 20-in. I-beams supported at the extremities like the other needles and wedged and cemented to solid bearing against the brick work. A similar recess was then cut across the opposite face at a little lower level and a pair of I-beams inserted in it and in a hole cut through the face of the adjacent wall so that the pier was carried by needle beams engaging shoulders on each side. To give it still further security a recess, at right angles to the first two was cut across the inner face of the pier and a short horizontal I-beam was seated in it and supported at both ends on the two needle beams already mentioned. The pier at the termination of the outer wall at the Broadway front had also a load of about 100 tons and was underpinned in the same manner. The Murray St. pier was braced by two 12x12-in. spur shores about 40 ft. long at right angles to each other, one of them reaching across the sidewalk and at a clear height sufficient to prevent obstructing it and the other at a somewhat smaller angle with the vertical being carried down to a footing in the bottom of the excavation. Both of these spurs had their square upper ends set in recesses cut in the brick walls and their lower ends adjusted by pairs of wedges on transverse horizontal sill pieces. An additional brace was provided by a 12x12-in. horizontal timber about 20 ft. long which was placed at an angle of 45 deg., with both of the underpinned walls which had recesses cut in them at the second floor level to receive the ends of the beam which were brought to bearings by pairs of wooden wedges driven by a man suspended in a boatswain's chair suspended from the roof at a height of about 40 ft. above the bottom of the excavation.

After the weight of the building was transferred to the 48x48-in. girders, six 12x12-in. inclined horizontal transverse braces were set with their lower ends engaging the long 48x48-in. girder and their upper ends engaging the lower horizontal ranger piece for the sheeting which retained the side of the excavation for the Murray St. vault. These braces were continued from the opposite side of the girder to footings of the old building thus providing balanced reaction and utilizing both the inertia and weight of the old building to resist the lateral thrust of the earth in the street. The upper rangers for the same sheeting were braced by transverse 12x12-in. struts inclined upwards in the same vertical planes as the lower struts. The opposite ends of these struts took bearing on 12-in. horizontal pieces about 6 ft. long laid against the face of the wall of the old building and distributing the pressure on it, thus acting both as for shores for the wall and as cross bracing for the retaining wall. The upper ends of these braces are supported by struts about 6 ft. long slightly inclined from the vertical with their lower ends seated in recesses cut in the face of the brick wall, their upper ends being stabbed to the lower surface of the 12x12-in. struts.

The sheeting around the sidewalk vault is made with 3x10-in. square edge planks about 24 ft. long driven as the excavation progressed, but having their lower ends always kept 3 or 4 ft. below the bottom of the pit. They were rapidly and economically driven by a No. 4 Ingersoll-Sargent steam drill having the rotating device removed and the drill bit replaced by a square ended bar striking on a heavy removable steel cap which enclosed the top of the pile. The sheeting is allowed to remain permanently in the ground, and is faced up on the inside with a 4-in. brick wall to which the water proofing is applied and after which the heavy foundation wall is built up against it. At the Murray St. pier the cross wall at the end of the vault was carried on vertical shores reaching to the foot of the excavation and located so that it was very difficult to remove them and they were permanently built in and enclosed by the outer brick work for the water proofing. At this point the excavation was very difficult and it was necessary to put the sheeting in with short vertical boards set and braced as fast as the pit was carried down.

The work was executed without difficulty from water and although very heavy and somewhat complicated has been done rapidly and successfully. The principal difficulty was to arrange the girders, piers and both systems of struts so as to clear the permanent structural work in the building and this has been done so successfully that it was only necessary to move one of the struts to permit the building of the brick work and the erection of the steel frame work.

As the excavation was carried down to subgrade the footings under the adjacent walls of the old building were removed and the basement floor was shored up when necessary. A new concrete footing and brick foundation wall was built in the bottom of the excavation up a height just clearing the lower flanges of the needle beams. Between the groups of needle beams brick piers were built a little higher and capped with pairs of cut stone. The upper stone was well covered with cement mortar and double steel wedges being driven between the stones, the mortar was forced up against the lower side of the old brick work, making a solid bed for the latter. The pairs of wedges were gradually driven until the weight of the wall was transferred from the needle beams to the piers between them and the needle beams were released, a condition which was indicated by the disappearance of their flexure as they sprung back to a horizontal position.

Marc Eidlitz & Son are the general contractors for the building and the underpinning and sheeting have been done by Miller, Daybill & Co., under the personal direction of Mr. Alfred Daybill.

A 7-Ft. Steel Pipe Line at St. Louis.

Among the improvements to the water supply system of St. Louis, Mo., that are under construction is a 7-ft. steel pipe flow line, 19,634 ft. in length. This flow line extends from a series of settling basins near a low service pumping station, at the Chain of Rocks, 10 miles above the central portion of the city, to a high-service pumping station in the northern end of the latter. Water is drawn from the Mississippi River by pumps in the low service station, from which it passes through the settling basins before being delivered to either of two high-service pumping stations that supply the distribution mains directly. A general description of the settling basins, including the design and construction of two large reinforced concrete basins was printed in The Engineering Record for July 6, 1907.

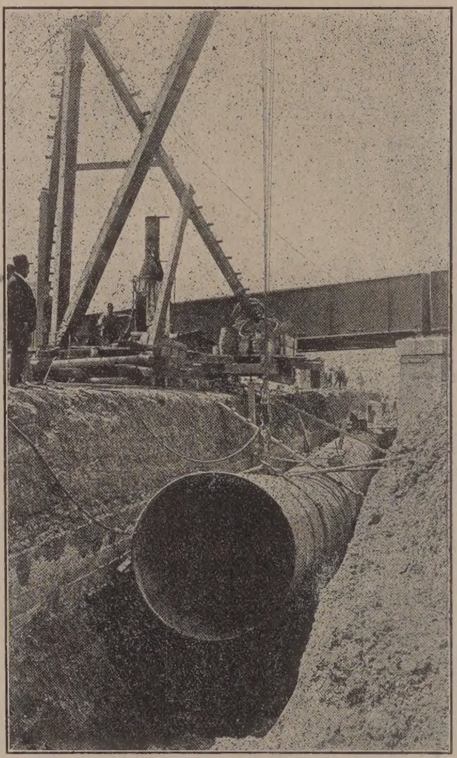
A horseshoe-shaped brick and masonry conduit, 11 ft. wide at the springing line of the arch and 9 ft, high, extends from these basins to the two high-service pumping stations at Baden and at Bissell's Point, the former being about 4 miles and the latter 7 miles down the river from the basins. Although this conduit has a sufficient carrying capacity to supply the two high-service stations, even during periods of maximum demand for water, it is at present the only means of conveying water to those stations, so the 7-ft. steel pipe line is being laid to the first high-service station to insure a supply at all times.

The new flow line starts at an outlet gate chamber near the down-stream end of the basins at the Chain of Rocks and parallels the brick and masonry conduit at varying distances to a 25,000,000-gal. storage reservoir at the Baden high-service station. The gate chamber from which the flow line starts has conduits connecting it with all of the settling basins, so water may be drawn into it from any of the latter. The pipe line is laid on a grade of about 6 in. to the mile from this chamber, which gives it an estimated carrying capacity of 35,000,000 gal. per 24 hours without head; it can, however, be operated under a 15-ft. head and will then deliver 10,000,000 gal. per 24 hours. It is nearly all in cut, only a few crossings of waterways being required. At most of these crossings the pipe line is close enough to the brick and masonry conduit so the crossings which were constructed when the latter was built are being extended to serve the pipe line.

A creek crossing about midway on the line requires the only bridge structure of any size. This bridge is a 137.5-ft. span having two Warren trusses with riveted connections, which are 14 ft. apart on centers, the height of the truss from center to center of chords being 11 ft. The bridge has a tight concrete roof and floor, both carried by transverse steel beams between the trusses. The floor system is designed to carry a live load of 50 lb. per square foot, in addition to its own weight, the weight of the 7-ft. flow line filled with water and the concrete supports of the flow line. The roof is proportioned to carry a uniform live load of 100 lb. per square foot in addition to its own weight. The wind pressure for which provision is made in the design is assumed to be acting horizontally in either direction at 30 lb. per square foot of a surface bounded by the extreme dimensions of the bridge. The allowable stresses of the steel and the methods of testing the latter are generally the same as those usually employed in railroad bridge design.

The pipe line is made of soft open-hearth steel plates ½ in. thick, and 84 in. wide, only one longitudinal joint being allowed to each plate. The steel is required to contain not more than 0.05 per cent. phosphorus, 0.05 per cent. sulphur, 0.05 per cent. silica and 0.5 per cent. manganese. The tensile strength specified is between 52,000 and 60,000 lb. per square inch, the elastic limit being required to reach at least 30,000 lb. per square inch. The pipe is assembled with taper rings in 28-ft. lengths, each made up of four rings. The small end of each ring at the transverse joint is inserted within the end of the next adjacent ring, the inside diameter of the small end of each ring being 84 in., and the inside diameter of its large end great enough so that the end will fit over the small end of the adjacent ring.

The lengths of pipe are tested at the mill under a hydraulic pressure of 30 lb. per square inch before being coated. After passing the test the lengths of pipe are cleaned and heated and are then dipped in a bath of mineral rubber asphalt coating. Suitable care is taken to protect this coating from the time the pipe is removed from the bath until it is accepted in place in the trench.


Laying Pipe in Close Quarters.

The construction of the pipe line presented no particular difficulties, as most of the trench excavation was in soil which stood well after the trench had been opened. The depth of cutting for about one-half the length of the line was under 12 ft. and for the remainder the cutting ran from 16 ft. to 22 ft. In the more shallow excavation the latter was made by hand, and in nearly all of this part of the work no shoring was required; shoring was employed, in fact on a very small percentage of the total amount of trench that has been opened.

A steam shovel mounted on a traveling platform is being used in making the excavation for the deeper sections of the trench, on which work is nearing completion. This platform, which is about the size of the platform on which a regular 20-ton Vulcan steam shovel is mounted, carries a boiler and a hoisting engine to operate the crane and dipper arm. The platform is carried by four 18-in. I-beams, 30 ft. long, two of which are placed across the trench under the front end of it and the other two under its rear end. These beams have truss rods connecting their ends, the latter resting on rollers on plank runways laid on both sides of the trench. These runways are back 2 ft. from the top of the trench and distribute the load on the sides of the latter to such extent that in the soil thus far encountered no caving has been caused by the load of the shovel outfit. The latter was built by the Vulcan Iron Works and removes the principal part of the excavation, the extra space required at the joints between the 28-ft. lengths, and extra trimming being done by hand.

The city of St. Louis operates a standard-gauge electric railway between the low-service and the two high-service pumping stations, which railway parallels the location of the 7-ft. flow line at a distance of 50 to 300 ft. This railway connects with steam railroads in the city, and on it has been delivered over 5,300 tons of the steel pipe required in building the flow line. The pipe was brought in over this line in the cars on which it was loaded at the mills and in a large portion of the trench was unloaded along the section of the trench it was to occupy, so little difficulty was encountered in pipe transportation.

The pipe is handled into the trench by a stiff-leg derrick set between the latter and the electric railway. Each 28-ft. section of pipe is lifted by one line around the center, this line being threaded through a hose to prevent injury to the coating of the pipe. The joints between the 28-ft. sections are made with pneumatic hammers supplied with an under pressure from either of two compressor outfits mounted on four-wheel trucks. One outfit has a 10x10-in. Laidlaw-Dunn-Gordon compressor and the other a 10x12-in. Curtis compressor, each of which is direct-connected to a 50-h. p. motor that receives power from the transmission line of the electric railway. They can be moved readily by one team and have been found very serviceable in this work.

The pipe line is tested, in lengths of approximately 2,000 ft., to a hydraulic pressure of 30 lb. per square inch. This pressure is maintained until all leaks in the entire section under pressure have been caulked and the pipe made tight.

The 25,000,000-gal. storage reservoir to which the 7-ft. flow line delivers at the upstream one of the two high-service pumping stations has only recently been completed. It has buttressed reinforced-concrete side walls and its bottom is lined with concrete. The excavation for the basin was nearly all made in dense limestone rock, the tops of the sides of the basin being about flush with the ground surface. The pipe line terminates in a gate house at the reservoir. A connection is made between this gate house and the reservoir, and a 60-in. hub-and-spigot cast-iron pipe is extended across the later on concrete pedestals, 10 ft. high, to the pumping station. The 7-ft. flow line is also connected through the gate chamber to the brick and masonry conduit from the settling basins at the low-service pumping station.

Mr. Ben C. Adkins is water commissioner, Mr. Edward E. Wall is assistant water commissioner and Mr. Arthur I. Jacobs is engineer of the supply and purifying division of the water department. The flow line is being built by the Parker-Washington Co., the work being under the direction of the St. Louis office of that company. The steel pipe was made by the Carroll-Porter Boiler & Tank Co. of Pittsburgh.

The Key West Extension of the Florida East Coast Ry. has been making rapid progress lately and construction trains are now running over half the distance from Miami to Key West. The more difficult half of the road is unfinished and it may be two years before it is ready for regular operation. There will be about 5¾ miles of concrete arches of a type already illustrated in The Engineering Record. Their spans are 50 to 60 ft. and they will rise about 30 ft. above the water. At one place the track is carried for 10,500 ft. on a succession of these arches.

Science and Engineering.

The relations between science and engineering were discussed in the opening address of the engineering section of the recent convention of the British Association for the Advancement of Science. The address was made by Dr. Silvanus P. Thompson who asserted at the outset that the astonishing development of the material resources of civilization is due to science. Chemistry, physics, mechanics and mathematics have furnished the means for this development, and the profession most potent in using them is that of engineering. The difference between the England of Edward the Seventh and of Edward the Sixth, between the Germany of William the Second and of Charles the Fifth is due more to the progress made in science and its applications than to the changes in politics, art, philosophy and religion. The following extracts from the address cover its leading topics:

In engineering, above all other branches of human effort, we are able to trace the close interaction between abstract science and its practical applications. Often as the connection between pure science and its applications has been emphasized in addresses upon engineering, the emphasis has almost always been laid upon the influence of the abstract upon the concrete. We are all familiar with the doctrine that the progress of science ought to be an end in itself, that scientific research ought to be pursued without regard to its immediate applications, that the importance of a discovery must not be measured by its apparent utility at the moment. We are assured that research in pure science is bound to work itself out in due time into technical applications of utility, and that the pioneer ought not to pause in his quest to work out potential industrial developments. We are invited to consider the example of the immortal Faraday, who deliberately abstained from busying himself with marketable inventions arising out of his discoveries, excusing himself on the ground that he had no time to spare for money-making. It is equally true, and equally to the point, that Faraday, when he had established a new fact, or a new physical relation, ceased from busying himself with it, and pronounced that it was now ready to be handed over to the mathematicians. But, admitting all these commonplaces as to the value of abstract science in itself and for its own sake, admitting also the proposition that sooner or later the practical applications are bound to follow on upon the discovery, it yet remains true that in this thing the temperament of the discoverer counts for something. There are scientific investigators who cannot pursue their work if troubled by the question of ulterior applications; there are others no less truly scientific who simply cannot work without the definiteness of aim that is given by a practical problem awaiting solution. There are Willanses as well as Regnaults; there are Whitworths as well as Poissons. The world needs both types of investigator; and it needs, too, yet another type of pioneer, namely, the man who, making no claim to original discovery, by patient application and intelligent skill turns to industrial fruitfulness the results already attained in abstract discovery.

There is, however, another aspect of the relation between pure and applied science, the significance of which has not been hitherto so much emphasized, but yet is none the less real—the reaction upon science and upon scientific discovery of the industrial applications.. For while pure science breeds useful inventions, it is none the less true that the industrial development of useful inventions fosters the progress of pure science. No one who is conversant with the history, for example, of optics can doubt that the invention of the telescope and the desire to perfect it were the principal factors in the outburst of optical science which we associated with the names of Newton, Huygens and Euler. The practical application, which we know was in the minds of each of these men, must surely have been the impelling motive that caused them to concentrate on abstract optics their great and exceptional powers of thought. Had there been no industrial development of the steam engine, is it at all likely that the world would ever have been enriched with the scientific researches of Rankine, Joule, Regnault, Hirn, or James Thomson?

Steam Shovel Used in Trench Work for 7-Foot Steel Pipe Line.

In considering this reflex influence of the industrial applications upon the progress of pure science it is of some significance to note that for the most part this influence is entirely helpful. There may be sporadic cases where industrial conditions tend temporarily to check progress by imposing persistence of a peculiar type of machine or appliance; but the general trend is always to help to new developments. The reaction aids the action; the law that is true enough in inorganic conservative systems, that reaction opposes the action, ceases here to be applicable, as, indeed, it ceases to be applicable in a vast number of organic phenomena. It is the very instability thereby introduced which is the essential of progress. The growing organism acts on its environment, and the change in the environment reacts on the organism—not in such a way as to oppose the growth, but so as to promote it. So is it with the development of pure science and its practical applications.

In further illustration of this principle one might refer to the immense effect which the engineering use of steel has had upon the study of the chemistry of the alloys. And the study of the alloys has in turn led to the recent development of metallography. It would even seem that through the study of the intimate structure of metals, prompted by the needs of engineers, we are within measurable distance of arriving at a knowledge of the secret of crystallogensis. Everything points to the probability of a very great and rapid advance in that fascinating branch of pure science at no distant date.

There is, however, one last example of the interaction of science and industry which may claim closer attention. In the history of the development of the electric motor one finds abundant illustration of both aspects of that interaction.

We go back to the year 1821, when Faraday, after studying the phenomena of electromagnetic deflexion of a needle by an electric current—Oersted's discovery—first succeeded in producing continuous rotations by electromagnetic means. In his simple apparatus a piece of suspended copper wire, carrying a current from a small battery, and dipping at its lower end into a cup of mercury, rotated continuously around the pole of a short bar-magnet of steel placed upright in the cup. In another variety of this experiment the magnet rotated around the central wire, which was fixed. These pieces of apparatus were the merest toys, incapable of doing any useful work; nevertheless, they demonstrated the essential principle and suggested further possibilities. Two years later, Barlow, using a star-wheel of copper, pivoted so that the lowest point of the star should make contact with a small pool of mercury, found that the star-wheel rotated if a current was sent through the arm of the star while the arm itself was situated between the poles of a steel horseshoe magnet. Shortly afterwards Sturgeon improved the apparatus by substituting a copper disc for the star-wheel. The action was the same. A conductor, carrying an electric current, if placed in a magnetic field, is found to experience a mechanical drag, which is neither an attraction nor a repulsion, but a lateral force tending to move it at right angles to the direction of flow of the current and at right angles to the direction of the lines of the magnetic field in which it is situated. Still this was a toy.

Two years later came the announcement by Sturgeon of the invention of the soft iron electro-magnet, one of the most momentous of all inventions, since upon it practically the whole of the constructive part of electrical engineering is based. For the first time mankind was furnished with a magnet, the attractive power of which could be increased absolutely indefinitely by the mere expenditure of sufficient capital upon the iron core and its surrounding copper coils, and the provision of a sufficiently powerful source of electric current to excite the magnetization. Furthermore, the magnet was under control, and could be made to attract or to cease to attract at will by merely switching the current on or off; and, lastly, this could be accomplished from a distance, even from great distances away. How slowly the importance of this discovery was recognized is now a matter for astonishment. To state that Sturgeon died in poverty twenty-six years later is sufficient to indicate his place among the unrequited pioneers of whom the world is not worthy. Six years elapsed and then there came a flood of suggestions of electric motors in which was applied the principle of intermittent attraction by an electro-magnet. Henry, in 1831, and Dal Negro, in 1832, produced see-saw mechanisms so operated. Ritchie, in 1833, and Jacobi, in 1834, devised rotatory motors. Ritchie pivoted a rapidly commutated electro-magnet between the poles of a permanent magnet—a true type of the modern motor—while Jacobi caused two multipolar electro-magnets, one fixed, one movable, to put a shaft into rotation and propel a boat. A perplexing diminution of the current of the battery whenever the motor was running caused Jacobi to investigate mathematically the theory of its action. In a masterly memoir he laid down a few years later the theory of electric motive power. But in the intervening period, in 1831, Faraday had made the cardinal discovery of the mechanical generation of electric currents by magneto-electric induction, the fundamental principle of the dynamo. Down to that date the only known way—save for the feeble currents of thermopiles—to generate electric currents had been the pile of Volta, or one of the forms of battery which had been evolved from it. Now, by Faraday's discovery, the world had become possessed of a new source. And yet again, strange as it may seem, years elapsed before the world—that is, the world of engineers —discovered that an important discovery had been made. Not till some thirty years later were any magneto-electric machines made of a sufficient size to be of practical service even in telegraphy, and none were built of a sufficient power to furnish a single electric light until about the year 1857. In the meantime in America other electric motors, to be driven by batteries, had been devised by Davenport and by Page; the latter's machine had an iron plunger to be sucked by electro-magnetic attraction into a hollow coil of copper wire, thereby driving a shaft and fly-wheel through the intermediate action of a connecting-rod and crank. Page's was, in fact, an electric engine, with 2-ft. stroke, single-acting, of between 3 and 4 h.-p. The battery occupied about 3 cu. ft., and consumed, according to Page, 3 lb. of zinc per horse-power per day. This must have been an under-estimate; for if Daniell's cells were used, the minimum consumption for a motor of 100 per cent. efficiency is known to be about 2 lb. of zinc per horse-power per hour.

An instructive view of the development of electric motors half a century ago can be obtained from a discussion of electro-magnetism as a motive power which was held in April, 1857, at the rooms of the Institution of Civil Engineers. On this occasion the most eminent engineers one and all condemned the idea of electric motive power as unpractical and commercially impossible. Even Faraday, in his lecture on Mental Education in 1854, had set down the magneto-electric engine along with mesmerism, homœopathy, odylism, the caloric engine, the electric light, the sympathetic compass, and perpetual motion as coming in different degrees amongst "subjects uniting more or less of the most sure and valuable investigations of science with the most imaginary and unprofitable speculation, that are continually passing through their various phases of intellectual, experimental, or commercial development, some to be established, some to disappear, and some to recur again and again, like ill weeds that cannot be extirpated, yet can be cultivated to no result as wholesome food for the mind."

Fifty years have fled, and Hunt, Grove, Smee, Tyndall, Cowper, Joule, Bidder and Stephenson have long passed away. Lord Kelvin remains the sole and honored survivor of that remarkable symposium. But the electric motor is a gigantic practical success and the electric motor industry has become a very large one, employing thousands of hands. Hundreds of factories have discarded their steam engines to adopt electric-motor driving. All traveling cranes, nearly all tramcars, are driven by electric motors. In the Navy and in much of the merchant service the donkey engines have been replaced by electric motors. Electric motors of all sizes and outputs, from one-twentieth of a horse-power to 8,000 horse-power, are in commercial use. One may well ask: What has wrought this astonishing revolution in the face of the unanimous verdict of the engineers of 1857? The answer may be given in terms of the action and reaction of pure and applied science. Pure science furnished a discovery; industrial applications forced its development; that development demanded further abstract investigation, which in turn brought about new applications. It was beyond all question the development of the dynamo for the purposes of electrotyping and electric light which brought about the commercial advent of the electric motor.

Interplay of action and reaction make for progress not only in the evolution of the scientific industries, but also in the development of the individual engineer. In him, if his training is on right lines, pure theory becomes an aid to sound practice; and practical applications are continually calling him to resort to those abstractions of thought, the underlying principles, which when known and formulated are called theories. Recent years have brought about a so much better understanding of education, in its bearing upon the professions and constructive industries, that we now seldom hear the practical man denouncing theory, or the theorist pooh-poohing practice. It is recognized that each is useful, and that the best uses of both are in conjunction, not in isolation. As a result of this better understanding distinct progress is being made in the training of engineers. Of this the growth of the engineering departments of the universities, and of the technical colleges and schools, affords striking evidence. The technical schools, moreover, are recognizing that their students must have a sound preliminary education and are advancing in the requirements they expect of candidates for admission. They are also finding out how their work may best supplement the practical training in the shops, and are improving their curricula accordingly. In the engineering industry, too, Great Bristain is slowly following the lead taken in America, Germany and Switzerland, in the recognition afforded to the value of a systematic college training for the young engineer, though there is still much apathy and even distrust shown in certain quarters. Yet there is no doubt that the stress of competition, particularly of competition against the industry and the enterprise of the trained men of other nations, is gradually forcing to the front the sentiment in favor of a rational and scientific training for the manufacturer and for the engineer.

Knowledge, perfected by study and training must be infused into the experience gained by practice; else we compete at very unequal odds with the systematically trained workers of other nations. Nor must we make the mistake here in the organization of our technical institutions of divorcing the theory from its useful applications. In no department is this more vital than in the teaching of mathematics to engineering students. For while no sane person would deny that the study of mathematics, for the sole sake of mathematics, even though it leads to nothing but abstract mathematics, is a high and ennobling pursuit, yet that is not the object of mathematical studies in an engineering school. The young engineer must learn mathematics, not as an end in itself, but as a tool that is to be useful to him. And if it is afterwards to be of use to him, he must learn it by using it. Hence the teacher of mathematics in an engineering school ought himself to be an engineer. However clever he be as a mathematical person, his teaching is unreal if he is not incessantly showing his learners how to apply it to the problems that arise in practice; and this he is incapable of doing if these problems do not lie within his own range of experience and knowledge. Were he a heaven-born senior wrangler, he is the wrong man to teach mathematics if he either despises or is ignorant of the ways in which mathematics enter into engineering. The fact is that for the great majority of engineering students, the mental training they most need is that which will enable them to think in physics, in mechanics, in geometric space, not in abstract symbols. The abstract symbols, and the processes of dealing with their relations and combinations, are truly necessary to them; but they are wanted not for themselves, but to form convenient modes of expressing the physical facts and laws, and the interdependence of those physical facts and laws. When the student looses grip of the physical meaning of his equations, and regards them only as abstractions or groupings of symbols, woe betide him. His mathematics amount to a mere symbol juggling. That is how paper engineers are made. The high and dry mathematical master who thinks it beneath him to show a student how to plot the equations $y = A \sin x$, or $r = b \sin \theta$, or who never culls an example or sets a problem from thermodynamics or electricity, must be left severely on one side as a fossil.

One evidence of the wholesome change of opinion that is springing up concerning the training of engineers is the abandonment of the system of taking premium pupils into works with no other test or qualification than that of the money-bag. Already many leading firms of engineers have been finding that the practice of taking sons of wealthy parents for a premium does not answer well, and is neither to their own advantage nor in many cases to that of the "pupil," whom it is nobody's particular business in the shops to train. Premium pupilage is absolutely unknown in the engineering firms of the United States or on the Continent of Europe. The firms who have abandoned it are finding themselves better served by taking the ablest young men from the technical schools and paying them small wages from the first, while they gain experience and prove themselves capable of good service. Messrs. Yarrow & Co. have led the way with a plan of their own, having three grades of apprenticeship, admission to which depends upon the educational abilities of the youths themselves. Messrs. Siemens have adopted a plan of requiring a high preliminary training. The Daimler Motor Company has likewise renounced all premiums, preferring to select young men of the highest intelligence and merit. Messrs. Clayton and Shuttleworth have quite recently reconstructed their system of pupil-apprenticeship on similar lines. The British Westinghouse Company and the British Thomson-Houston Company have each followed an excellent scheme for the admission of capable young men. Even the conservatism of the railway engineers shows signs of giving way; for already the Great Eastern Railway has modernized its regulations for the admission of apprentices. What the engineering staffs of the railway companies have lost by taking in pupils because of their fathers' purses rather than for the sake of their own brains it is impossible to gauge. But the community loses too, and has a right to expect reform.

A Unit Table for Talbot's Spiral.

The accompanying table based on Talbot's Spiral has been compiled by Mr. G. A. Kyle, principal assistant engineer of the Chicago, Milwaukee & St. Paul Ry., of Washington, for use on the Pacific extension west of Butte, Mont. Professor Talbot's formulas are used, the only departures being in symbols and in the form of the equations for obtaining deflections from points on the spiral other than the beginning or initial point. The unit table is developed to a limited extent in the printed editions of this easement curve, but the table presented here is adapted to any length up to 400 ft. varying by whole feet.

Most spiral tables are based on a fixed chord length and when a certain chord has been chosen no other points than those tabulated can be set without the use of complicated formulas. With the spiral under consideration, however, the chord lengths can be chosen of any length to suit local requirements, since fractional chord lengths do not involve any extra labor of computation. This advantage is readily appreciated when points are required for trestle bents, or when it is impossible to set stakes at the full chord points.

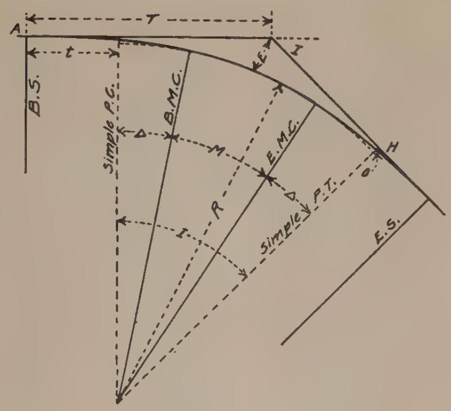


Figure 1.

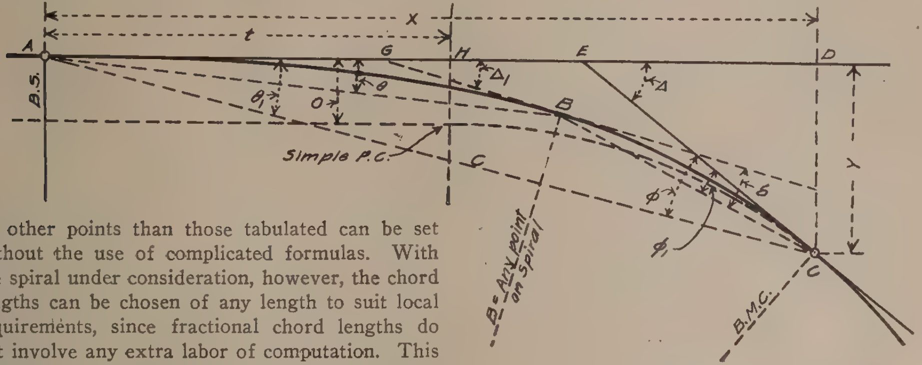


Figure 2.

Attention is called to the use of the terms B. S., beginning of spiral, B. M. C., beginning of main curve, E. M. C., end of main curve, and E. S. end of spiral. There are a number of minor departures from Professor Talbot's notation, and a new symbol, δ, is introduced, indicating a deflection angle turned from the tangent to the spiral at any point, except the B. S., to the B. M. C. For this angle a special formula has been derived which is used instead of the general equation—

$$\phi = \tfrac{1}{2}\, a\, L^1 (L - L^1) \mp \tfrac{1}{6}\, a\, (L - L^1)^2$$

where L is the distance along the spiral from the B. S. to the point to be located, and L^1 is the distance from the B. S. to the point where the instrument is set up. The equation for ϕ_1 is also a special case of the above general equation, and it will be noted that if it be desired to set points between the B. S. and an intermediate point on the spiral at which the instrument is set up, that the equation for ϕ_1 may be used by merely assuming that the instrument point for the time being is the B. M. C. The angles δ, ϕ and ϕ_1 are always between a tangent to the spiral at the point considered and a chord to some other point on the spiral. To get on tangent at any point on the spiral when the B. S. can be seen it is only necessary to turn off the angle ϕ, backsighting on the latter point. The quantities A, d and d_1 are also original with this table.

The equation for the length of the spiral was evolved by Mr. Kyle in a modified form in 1900, while he was division engineer on the Northern Pacific Ry. at Tacoma. The equation is

$$L = V E$$

where L = length of spiral in feet; V velocity of the train in miles per hour; and E = elevation in track in inches for speed V. This formula is explained by its author as follows:

"Before spiral curves were used it was a common and almost uniform practice on Western roads to attain the difference in elevation of rails on curves by an approach usually on the tangent but sometimes one-half on the tangent and one-half on the curve, allowing 60 ft. in which to attain 1 in. difference in elevation, the maximum speed being assumed at 45 miles per hour. Then, to find the distance required to attain 1 in. difference in elevation of rails at any other speed, allowing the same time to attain a fixed elevation, the procedure was as follows:

SPIRAL LENGTHS FOR DIFFERENT SPEEDS AND CURVATURE.

Deg.	25	30	35	40	45	50	55	60	Miles per Hr.
of Curve.	10	5	3⅓	2½	1⅔	1¼	1	7/10	Values of a.
1°	10	20	30	40	60	80	100	142.8	
1° 30′	15	30	45	60	90	120	150	214.2	
2°	20	40	60	80	120	160	200	285.6	
2° 30′	25	50	75	100	150	200	250	357.0	
3°	30	60	90	120	180	240	300		
3° 30′	35	70	105	140	210	280			
4°	40	80	120	160	240				
4° 30′	45	90	135	180	270				
5°	50	100	150	200					
5° 30′	55	110	185	220					
6°	60	120	180						
6° 30′	65	130	195						
7°	70	140	210						
7° 30′	75	150							
8°	80	160							
8° 30′	85	170							
9°	90	180							
9° 30′	95	190							
10°	100	200							
10° 30′	105	210							
11°	110								

Let E equal difference in elevation of tracks in inches on main curve.
V^1 " maximum velocity in miles per hour assumed in raising 1 in. in distance D^1.
D^1 " distance assumed in which to raise 1 in. at V^1 miles per hour.
V " velocity of train in question.
D " distance required to raise 1 in. at V miles per hour.
L " length of incline required to attain elevation E at V miles per hour assumed to be the correct length of spiral curve.

Then, to find the distance D required at any speed V to attain 1 in. difference in elevation of rails we have,

$$D = D^1 V \div V^1 \qquad (1)$$

inserting the assumed values of D and V, we have

$$D = 60\, V \div 45 = 1\tfrac{1}{3}\, V$$

and to attain the whole elevation E

$$L = 1\tfrac{1}{3}\, VE \text{ or } L = D^1 VE \div V^1 \qquad (2)$$

Later it was found that this gave an excessive length of curve and the original assumptions were changed so that the maximum speed should be 50 instead of 45 miles per hour, and the distance required to attain 1 in. in elevation at 50 miles per hour was taken as 50 instead of 60 ft.

Inserting the above figures in the formula $L = D^1 VE \div V^1$ we have $L = V E \qquad (3)$

The formula now in use is theoretically correct, assuming that the constants and distance in which to raise 1 in. are based on the proper

UNIT TABLE FOR TALBOT'S SPIRAL.

L	D	Θ	φ	Δ	X	C	t	U & V	Y	O
	Deg.				Cor.	Cor.	Cor.	Cor.		
in 100 ft. Stations.	and Min.	Min.	Min.	Min.	Minus.	Minus.	Minus.	Plus.	Ft.	Ft.
.01	0-0.6	0.001	0.002	0.003	0.	0.	0.	0.	.00001	.0000002
.02	0-1.2	0.004	0.008	0.012	0.	0.	0.	0.	.00002	.000005
.03	0-1.8	0.01	0.02	0.03	0.	0.	0.	0.	.00003	.000006
.04	0-2.4	0.02	0.03	0.05	0.	0.	0.	0.	.00003	.000008
.05	0-3.0	0.03	0.05	0.08	0.	0.	0.	0.	.00004	.00001
.06	0-3.6	0.04	0.07	0.11	0.	0.	0.	0.	.00005	.00002
.07	0-4.2	0.05	0.10	0.15	0.	0.	0.	0.	.0001	.00003
.08	0-4.8	0.06	0.13	0.19	0.	0.	0.	0.	.0002	.00005
.09	0-5.4	0.08	0.16	0.24	0.	0.	0.	0.	.0003	.00007
.10	0-6.0	0.10	0.20	0.30	0.	0.	0.	0.	.0003	.00008
.11	0-6.6	0.12	0.24	0.36	0.	0.	0.	0.	.0004	.0001
.12	0-7.2	0.14	0.29	0.43	0.	0.	0.	0.	.0006	.0001
.13	0-7.8	0.17	0.34	0.51	0.	0.	0.	0.	.0008	.0002
.14	0-8.4	0.20	0.39	0.59	0.	0.	0.	0.	.0009	.0002
.15	0-9.0	0.23	0.46	0.69	0.	0.	0.	0.	.001	.0003
.16	0-9.6	0.26	0.52	0.78	0.	0.	0.	0.	.001	.0003
.17	0-10.2	0.29	0.58	0.87	0.	0.	0.	0.	.001	.0004
.18	0-10.8	0.32	0.64	0.96	0.	0.	0.	0.	.002	.0005
.19	0-11.4	0.36	0.72	1.08	0.	0.	0.	0.	.002	.0005
.20	0-12.0	0.40	0.80	1.20	0.	0.	0.	0.	.002	.0006
.21	0-12.6	0.44	0.88	1.32	0.	0.	0.	0.	.003	.0007
.22	0-13.2	0.48	0.96	1.44	0.	0.	0.	0.	.003	.0007
.23	0-13.8	0.53	1.06	1.59	0.	0.	0.	0.	.004	.001
.24	0-14.4	0.58	1.16	1.74	0.	0.	0.	0.	.004	.001
.25	0-15.0	0.63	1.26	1.89	0.	0.	0.	0.	.005	.001
.26	0-15.6	0.68	1.36	2.04	0.	0.	0.	0.	.006	.001
.27	0-16.2	0.73	1.46	2.19	0.	0.	0.	0.	.006	.001
.28	0-16.8	0.78	1.56	2.34	0.	0.	0.	0.	.007	.002
.29	0-17.4	0.84	1.68	2.52	0.	0.	0.	0.	.007	.002
.30	0-18.0	0.90	1.80	2.70	0.	0.	0.	0.	.008	.002
.31	0-18.6	0.96	1.92	2.88	0.	0.	0.	0.	.009	.002
.32	0-19.2	1.02	2.04	3.06	0.	0.	0.	0.	.009	.002
.33	0-19.8	1.09	2.18	3.27	0.	0.	0.	0.	.010	.003
.34	0-20.4	1.16	2.32	3.48	0.	0.	0.	0.	.011	.003
.35	0.21.0	1.23	2.46	3.69	0.	0.	0.	0.	.012	.003
.36	0-21.6	1.30	2.60	3.90	0.	0.	0.	0.	.013	.004
.37	0-22.2	1.37	2.74	4.11	0.	0.	0.	0.	.015	.004
.38	0-22.8	1.44	2.88	4.32	0.	0.	0.	0.	.016	.004
.39	0-23.4	1.52	3.04	4.56	0.	0.	0.	0.	.018	.004
.40	0-24.0	1.60	3.20	4.80	0.	0.	0.	0.	.019	.005
.41	0-24.6	1.70	3.40	5.10	0.	0.	0.	0.	.020	.005
.42	0-25.2	1.80	3.60	5.40	0.	0.	0.	0.	.022	.005
.43	0-25.8	1.85	3.70	5.55	0.	0.	0.	0.	.023	.006
44	0-26.4	1.90	3.80	5.70	0.	0.	0.	0.	.025	.006

(Continued on page 260.)

usage. It takes into account the constant time function required to attain a fixed elevation, and the mechanical difficulties for the trucks to assume their radial position on the main curve.

The elevation E on curves is represented by the formula

$$E = Gv^2 \div 32.2R$$

in which G is the gauge of track, 4.71 ft.

E equals elevation main curve in inches.

v equals velocity of train in feet per second = $1.4667\,V$.

V equals velocity of train in miles per hour.

R equals radius of main curve in feet equals $5730/D$ (approximately), equals degree of main curve.

Substituting values of V^2R and G in the above equation.

$$E = (4.71 \times 1.4667^2\ V^2 D) \div (32.2 \times 5730) = 0.00005491\ V^2\ D \text{ (in feet)}$$

Reducing by multiplying last half of equation (3) by 12

$E = .00005491\ V^2\ D \times 12 = .00065892\ V^2\ D.$ Substituting value of E in equation $L = V\ E.$ $L = .00065892\ V^3\ D$ (4)

in which the length of spiral curve varies as the cube of velocity and as the degree of curve."

This equation $L = V\ E$ is also used by Mr. J. R. Stephens in "The Six-Chord Spiral," as the proper length of spiral curve.

A study of the formulas here given will explain the use of the unit table, which has been so named because it gives quantities computed for a value of a, the rate of change of the spiral per station, of unity. All the elements of the curve are functions of a, and to use the table for any particular case it is merely necessary to multiply the tabulated values by the a, or square of the a, selected for the case in hand. The quantities D, θ, ϕ, Δ, Y and O vary directly as a, and X, c, t, U and V vary as a^2. The quantities in the correction columns for the latter group must therefore be multiplied by the square of the a selected.

The use of the various corrections tabulated are evident from an inspection of the formulas. To obtain x or c the corresponding correction is subtracted from the spiral length from B. S. to the point to be located, the t correction is subtracted from half the length, the U correction added to 2/3 the length, and the V correction to 1/3 the length, the length being expressed in feet. It will be noted that these corrections all vary as the square of a.

The table here given takes the place of the dozen or more tables usually necessary for using any spiral, and embodies all possible spirals varying by whole feet up to 400 ft. Any length of spiral or any rate of change can be used, and the only operation necessary is a simple multiplication.

An additional table also presented here gives the values of a and the lengths of spiral used by the road for different speeds and degrees of curvature. The instructions issued with the table give the following rules: "The maximum speed on main line will be 50 miles per hour generally, excepting on mountain grades, sharp curves or points on line where instructions direct speed to be reduced.

"The maximum elevation is not to exceed 6 in. except in sags or at points where speed may be higher than the maximum speed above indicated. (See instructions for elevating on curves.)

"The table gives the nearest even lengths of spirals and their respective values of a for different speeds and degrees of curvature which will be made the standard and will be used by all engineers. For any other degree of curvature the length of spiral will vary as the degree of curvature and for any other speed will vary as the cube of the speed. In all cases leave a

UNIT TABLE FOR TALBOT'S SPIRAL.—Continued.

L in 100 ft. Stations.	D Deg. and Min.	θ Min.	φ Min.	Δ Min.	X Cor. Minus.	C Cor. Minus.	t Cor. Minus.	U & V Cor. Plus.	Y Ft.	O Ft.
.45	0-27.0	2.00	4.00	6.00	0.	0.	0.	0.	.026	.007
.46	0-27.6	2.10	4.20	6.30	0.	0.	0.	0.	.028	.007
.47	0-28.2	2.20	4.40	6.60	0.	0.	0.	0.	.030	.008
.48	0-28.8	2.30	4.60	6.90	0.	0.	0.	0.	.032	.008
.49	0-29.4	2.40	4.80	7.20	0.	0.	0.	0.	.034	.008
.50	0-30.0	2.50	5.00	7.50	0.	0.	0.	0.	.036	.009
.51	0-30.6	2.60	5.20	7.80	0.	0.	0.	0.	.038	.009
.52	0-31.2	2.70	5.40	8.10	0.	0.	0.	0.	.041	.010
.53	0-31.8	2.80	5.60	8.40	0.	0.	0.	0.	.043	.011
.54	0-32.4	2.90	5.80	8.70	0.	0.	0.	0.	.046	.011
.55	0-33.0	3.00	6.00	9.00	0.	0.	0.	0.	.048	.012
.56	0-33.6	3.10	6.20	9.30	0.	0.	0.	0.	.051	.013
.57	0-34.2	3.30	6.60	9.90	0.	0.	0.	0.	.054	.014
.58	0-34.8	3.40	6.80	10.20	0.	0.	0.	0.	.057	.014
.59	0-35.4	3.50	7.00	10.50	0.	0.	0.	0.	.060	.015
.60	0-36.0	3.60	7.20	10.80	0.	0.	0.	0.	.063	.016
.61	0-36.6	3.70	7.40	11.10	0.	0.	0.	0.	.066	.017
.62	0-37.2	3.80	7.60	11.40	0.	0.	0.	0.	.070	.018
.63	0-37.8	4.00	8.00	12.00	0.	0.	0.	0.	.073	.018
.64	0-38.4	4.10	8.20	12.30	0.	0.	0.	0.	.077	.019
.65	0-39.0	4.20	8.40	12.60	0.	0.	0.	0.	.080	.020
.66	0-39.6	4.40	8.80	13.20	0.	0.	0.	0.	.084	.021
.67	0-40.2	4.50	9.00	13.50	0.	0.	0.	0.	.088	.022
.68	0-40.8	4.60	9.20	13.80	0.	0.	0.	0.	.092	.023
.69	0-41.4	4.80	9.60	14.40	0.	0.	0.	0.	.096	.024
.70	0-42.0	4.90	9.80	14.70	0.	0.	0.	0.	.100	.025
.71	0-42.6	5.00	10.00	15.00	0.	0.	0.	0.	.105	.026
.72	0-43.2	5.20	10.40	15.60	0.	0.	0.	0.	.109	.027
.73	0-43.8	5.30	10.60	15.90	0.	0.	0.	0.	.114	.028
.74	0-44.4	5.50	11.00	16.50	0.	0.	0.	0.	.118	.029
.75	0-45.0	5.60	11.20	16.80	0.0002	0.	0.	0.	.123	.031
.76	0-45.6	5.80	11.60	17.40	0.0002	0.	0.	0.	.128	.032
.77	0-46.2	5.90	11.80	17.70	0.0002	0.	0.	0.	.133	.033
.78	0-46.8	6.10	12.20	18.30	0.0002	0.	0.	0.	.139	.035
.79	0-47.2	6.20	12.40	18.60	0.0002	0.0001	0.	0.	.144	.036
.80	0-47.8	6.40	12.80	19.20	0.0003	0.0001	0.	0.	.149	.037
.81	0-48.6	6.60	13.20	19.80	0.0003	0.0001	0.	0.	.155	.039
.82	0-49.2	6.70	13.40	20.10	0.0003	0.0001	0.	0.	.161	.040
.83	0-49.8	6.90	13.80	20.70	0.0003	0.0001	0.	0.	.167	.042
.84	0-50.4	7.10	14.20	21.30	0.0003	0.0001	0.	0.	.173	.043
.85	0-51.0	7.20	14.40	21.60	0.0003	0.0001	0.	0.	.179	.045
.86	0-51.6	7.40	14.80	22.20	0.0003	0.0001	0.	0.	.186	.046
.87	0.52.2	7.60	15.20	22.80	0.0004	0.0002	0.	0.	.192	.048
.88	0-52.8	7.70	15.40	23.10	0.0004	0.0002	0.	0.	.199	.050
.89	0-53.4	7.90	15.80	23.70	0.0004	0.0002	0.	0.	.205	.051
.90	0-54.0	8.10	16.20	24.30	0.0004	0.0002	0.	0.	.212	.053
.91	0-54.6	8.30	16.60	24.90	0.0004	0.0002	0.	0.	.219	.055
.92	0-55.2	8.50	17.00	25.50	0.0005	0.0003	0.	0.	.227	.057
.93	0-55.8	8.70	17.40	26.10	0.0005	0.0003	0.	0.	.234	.058
.94	0-56.4	8.80	17.60	26.40	0.0005	0.0003	0.	0.	.242	.060
.95	0-57.0	9.00	18.00	27.00	0.0005	0.0003	0.	0.	.249	.062
.96	0-57.6	9.20	18.40	27.60	0.0006	0.0003	0.	0.	.257	.064
.97	0-58.2	9.40	18.80	28.20	0.0007	0.0003	0.	0.	.266	.066
.98	0-58.8	9.60	19.20	28.80	0.0007	0.0003	0.	0.	.274	.068
.99	0-59.4	9.80	19.60	29.40	0.0007	0.0003	0.	0.	.283	.071
1.00	1-00.0	10.00	20.00	30.00	0.0007	0.0003	0.	0.	.291	.073
1.01	1-00.6	10.20	20.40	30.60	0.0008	0.0004	0.	0.	.300	.075
1.02	1-01.2	10.40	20.80	31.20	0.0008	0.0004	0.	0.	.309	.077
1.03	1-01.8	10.60	21.20	31.80	0.0009	0.0004	0.	0.	.319	.080
1.04	1-02.4	10.80	21.60	32.40	0.0009	0.0004	0.	0.	.328	.082
1.05	1-03.0	11.00	22.00	33.00	0.0010	0.0005	0.	0.	.337	.084
1.06	1-03.8	11.20	22.40	33.60	0.0010	0.0005	0.	0.	.347	.087
1.07	1-04.2	11.50	23.00	34.50	0.0010	0.0005	0.	0.	.357	.089
1.08	1-04.8	11.70	23.40	35.10	0.0010	0.0005	0.	0.	.367	.092
1.09	1-05.4	11.90	23.80	35.70	0.0010	0.0005	0.	0.	.377	.094
1.10	1-06.0	12.10	24.20	36.30	0.0012	0.0005	0.	0.	.387	.097
1.11	1-06.6	12.30	24.60	36.90	0.0013	0.0006	0.	0.	.398	.099
1.12	1-07.2	12.50	25.00	37.50	0.0013	0.0006	0.	0.	.409	.102
1.13	1-07.8	12.80	25.60	38.40	0.0014	0.0006	0.	0.	.420	.105
1.14	1-08.4	13.00	26.00	39.00	0.0015	0.0007	0.	0.	.431	.108
1.15	1-09.0	13.20	26.40	39.60	0.0015	0.0007	0.	0.	.442	.111
1.16	1-09.6	13.50	27.00	40.50	0.0016	0.0007	0.	0.	.454	.114
1.17	1-10.2	13.70	27.40	41.10	0.0016	0.0007	0.	0.	.466	.117
1.18	1-10.8	13.90	27.80	41.70	0.0017	0.0008	0.	0.	.479	.120
1.19	1-11.4	14.20	28.40	42.60	0.0018	0.0008	0.	0.	.491	.123
1.20	1-12.0	14.40	28.80	43.20	0.0019	0.0009	0.0003	0.0006	.503	.126
1.21	1-12.6	14.60	29.20	43.80	0.0019	0.0009	0.0003	0.0006	.516	.129
1.22	1-13.2	14.90	29.80	44.70	0.0020	0.0009	0.0003	0.0006	.529	.132
1.23	1-13.8	15.10	30.20	45.30	0.0021	0.0009	0.0004	0.0007	.542	.135
1.24	1-14.4	15.40	30.80	46.20	0.0022	0.0010	0.0004	0.0008	.555	.139
1.25	1-15.0	15.60	31.20	46.30	0.0023	0.0010	0.0004	0.0008	.568	.142
1.26	1-15.6	15.90	31.80	47.70	0.0024	0.0011	0.0004	0.0008	.582	.145
1.27	1-16.2	16.10	32.20	48.30	0.0025	0.0011	0.0004	0.0008	.596	.149
1.28	1-16.8	16.40	32.80	49.20	0.0026	0.0012	0.0004	0.0008	.611	.153
1.29	1-17.4	16.60	33.20	49.80	0.0027	0.0012	0.0004	0.0008	.625	.156
1.30	1-18.0	16.90	33.80	50.70	0.0028	0.0013	0.0005	0.0009	.639	.160
1.31	1-18.6	17.20	34.40	51.60	0.0029	0.0013	0.0005	0.001	.654	.163
1.32	1-19.2	17.40	34.80	52.20	0.0030	0.0014	0.0005	0.001	.670	.167
1.33	1-19.8	17.70	35.40	53.10	0.0032	0.0014	0.0005	0.001	.685	.171
1.34	1-20.4	18.00	36.00	54.00	0.0033	0.0015	0.0005	0.001	.701	.175
1.35	1-21.0	18.20	36.40	54.60	0.0034	0.0015	0.0006	0.001	.716	.179
1.36	1-21.6	18.50	37.00	55.50	0.0035	0.0016	0.0006	0.001	.732	.183
1.37	1-22.2	18.80	37.60	56.40	0.0037	0.0016	0.0006	0.001	.749	.187
1.38	1-22.8	19.00	38.00	57.00	0.0039	0.0017	0.0006	0.001	.765	.191
1.39	1-23.4	19.30	38.60	57.90	0.0040	0.0018	0.0007	0.001	.782	.195
1.40	1-24.0	19.60	39.20	58.80	0.0041	0.0018	0.0007	0.001	.798	.199
1.41	1-24.6	19.90	39.80	59.70	0.0043	0.0020	0.0007	0.002	.816	.204
1.42	1-25.2	20.20	40.40	60.60	0.0044	0.0021	0.0007	0.002	.834	.208
1.43	1-25.8	20.40	40.80	61.20	0.0046	0.0022	0.0008	0.002	.851	.213
1.44	1-26.4	20.70	41.40	62.10	0.0047	0.0022	0.0008	0.002	.869	.217
1.45	1-27.0	21.00	42.00	63.00	0.0049	0.0023	0.0008	0.002	.887	.221
1.46	1-27.6	21.30	42.60	63.90	0.0051	0.0023	0.0009	0.002	.906	.226
1.47	1-28.2	21.60	43.20	64.80	0.0053	0.0024	0.0009	0.002	.925	.231
1.48	1-28.8	21.90	43.80	65.70	0.0054	0.0024	0.0009	0.002	.944	.236
1.49	1-29.4	22.20	44.40	66.60	0.0056	0.0025	0.0009	0.002	.963	.241
1.50	1-30.0	22.50	45.00	67.50	0.0058	0.0026	0.001	0.002	.982	.245
1.51	1-30.6	22.80	45.60	68.40	0.0060	0.0027	0.001	0.002	1.002	.250
1.52	1-31.2	23.10	46.20	69.30	0.0062	0.0028	0.001	0.002	1.022	.255
1.53	1-31.8	23.40	46.80	70.20	0.0064	0.0029	0.001	0.002	1.043	.261
1.54	1-32.4	23.70	47.40	71.10	0.0066	0.0030	0.001	0.002	1.063	.266
1.55	1-33.0	24.00	48.00	72.00	0.0068	0.0031	0.001	0.002	1.083	.271
1.56	1-33.6	24.30	48.60	72.90	0.007	0.0032	0.001	0.002	1.105	.276
1.57	1-34.2	24.60	49.20	73.30	0.007	0.0032	0.001	0.002	1.127	.282
1.58	1-34.8	25.00	50.00	75.00	0.008	0.0032	0.001	0.003	1.148	.287
1.59	1-35.4	25.30	50.60	75.90	0.008	0.0034	0.001	0.003	1.170	.292
1.60	1-36.0	25.60	51.20	76.80	0.008	0.0034	0.001	0.003	1.192	.298
1.61	1-36.6	25.90	51.80	77.70	0.008	0.0034	0.001	0.003	1.215	.304
1.62	1-37.2	26.20	52.40	78.60	0.009	0.0036	0.001	0.003	1.238	.309
1.63	1-37.8	26.60	53.20	79.80	0.009	0.0037	0.001	0.003	1.261	.315
1.64	1-38.4	26.90	53.80	80.70	0.009	0.0037	0.001	0.003	1.284	.321
1.65	1-39.0	27.20	54.40	81.60	0.009	0.0038	0.002	0.003	1.307	.327
1.66	1-39.6	27.60	55.20	82.80	0.010	0.004	0.002	0.003	1.331	.333
1.67	1-40.2	27.90	55.80	83.70	0.010	0.004	0.002	0.003	1.356	.339
1.68	1-40.8	28.20	56.40	84.60	0.010	0.004	0.002	0.003	1.380	.345

(Continued on page 261.)

UNIT TABLE FOR TALBOT'S SPIRAL.—Continued.

L in 100 ft. Stations.	D Deg. and Min.	θ Min.	φ Min.	Δ Min.	X Cor. Minus.	C Cor. Minus.	t Cor. Minus.	U & V Cor. Plus.	Y Ft.	O Ft.
1.69	1-41.4	28.60	57.20	85.80	0.010	0.004	0.002	0.004	1.405	.351
1.70	1-42.0	28.90	57.80	86.70	0.010	0.005	0.002	0.004	1.429	.357
1.71	1-42.6	29.20	58.40	87.60	0.011	0.005	0.002	0.004	1.455	.364
1.72	1-43.2	29.60	59.20	88.80	0.011	0.005	0.002	0.004	1.487	.370
1.73	1-43.8	29.90	59.80	89.70	0.012	0.005	0.002	0.004	1.507	.377
1.74	1-44.4	30.30	60.60	90.90	0.012	0.005	0.002	0.004	1.533	.383
1.75	1-45.0	30.60	61.20	91.80	0.012	0.006	0.002	0.004	1.559	.390
1.76	1-45.6	31.00	62.00	93.00	0.013	0.006	0.002	0.004	1.587	.397
1.77	1-46.2	31.30	62.60	93.90	0.013	0.006	0.002	0.004	1.614	.404
1.78	1-46.8	31.70	63.40	95.10	0.014	0.006	0.002	0.005	1.642	.410
1.79	1-47.4	32.00	64.00	96.00	0.014	0.006	0.002	0.005	1.669	.417
1.80	1-48.0	32.40	64.80	97.20	0.014	0.006	0.003	0.005	1.697	.424
1.81	1-48.6	32.80	65.60	98.40	0.015	0.007	0.003	0.005	1.726	.431
1.82	1-49.2	33.10	66.20	99.30	0.015	0.007	0.003	0.005	1.755	.439
1.83	1-49.8	33.50	67.00	100.5	0.016	0.007	0.003	0.006	1.784	.446
1.84	1-50.4	33.90	67.80	101.7	0.016	0.007	0.003	0.006	1.813	.453
1.85	1-51.0	34.20	68.40	102.6	0.016	0.007	0.003	0.006	1.843	.461
1.86	1-51.6	34.60	69.20	103.8	0.017	0.008	0.003	0.006	1.873	.469
1.87	1-52.2	35.00	70.00	105.0	0.017	0.008	0.003	0.006	1.903	.476
1.88	1-52-8	35.30	70.60	105.9	0.018	0.008	0.003	0.006	1.934	.484
1.89	1-53.4	35.70	71.40	107.1	0.018	0.008	0.003	0.006	1.964	.491
1.90	1-54.0	36.10	72.20	108.3	0.018	0.008	0.003	0.006	1.995	.499
1.91	1-54.6	36.50	73.00	109.5	0.019	0.009	0.003	0.006	2.027	.507
1.92	1-55.2	36.90	73.80	110.7	0.020	0.009	0.003	0.007	2.060	.515
1.93	1-55.8	37.20	74.40	111.6	0.020	0.009	0.003	0.007	2.092	.523
1.94	1-56.4	37.60	75.20	112.8	0.021	0.009	0.004	0.007	2.125	.531
1.95	1-57.0	38.00	76.00	114.0	0.021	0.009	0.004	0.007	2.157	.539
1.96	1-57.6	38.40	76.80	115.2	0.022	0.010	0.004	0.007	2.191	.548
1.97	1-58.2	38.80	77.60	116.4	0.023	0.010	0.004	0.008	2.225	.556
1.98	1-58.8	39.20	78.40	117.6	0.023	0.010	0.004	0.008	2.259	.565
1.99	1-59.4	39.60	79.20	118.8	0.024	0.011	0.004	0.008	2.293	.573
2.00	2-00.0	40.00	80.00	120.0	0.024	0.011	0.004	0.008	2.327	.582
2.01	2-00.6	40.40	80.80	121.2	0.025	0.011	0.004	0.008	2.363	.591
2.02	2-01.2	40.80	81.60	122.4	0.026	0.012	0.004	0.009	2.399	.600
2.03	2-01.8	41.20	82.40	123.6	0.026	0.012	0.004	0.009	2.434	.609
2.04	2-02.4	41.60	83.20	124.8	0.027	0.012	0.005	0.009	2.470	.618
2.05	2-03.0	42.00	84.00	126.0	0.027	0.013	0.005	0.009	2.506	.627
2.06	2-03.6	42.40	84.80	127.2	0.028	0.013	0.005	0.009	2.544	.636
2.07	2-04.2	42.80	85.60	128.4	0.029	0.013	0.005	0.010	2.581	.645
2.08	2-04.8	43.30	86.60	129.9	0.030	0.013	0.005	0.010	2.619	.655
2.09	2.05.4	43.70	87.40	131.1	0.030	0.014	0.005	0.010	2.656	.664
2.10	2-06.0	44.10	88.20	132.3	0.031	0.014	0.005	0.010	2.694	.674
2.11	2-06.6	44.50	89.00	133.5	0.032	0.014	0.005	0.011	2.733	.683
2.12	2-07.2	44.90	89.80	134.7	0.033	0.015	0.005	0.011	2.773	.693
2.13	2-07.8	45.40	90.80	136.2	0.033	0.015	0.006	0.011	2.812	.703
2.14	2-08.4	45.80	91.60	137.4	0.034	0.015	0.006	0.011	2.852	.713
2.15	2-09.0	46.20	92.40	138.6	0.035	0.016	0.006	0.012	2.891	.723
2.16	2-09.6	46.70	93.40	140.1	0.036	0.016	0.006	0.012	2.932	.733
2.17	2-10.2	47.10	94.20	141.3	0.037	0.017	0.006	0.012	2.974	.743
2.18	2-10.8	47.50	95.00	142.5	0.037	0.017	0.006	0.012	3.015	.754
2.19	2-11.4	48.00	96.00	144.0	0.038	0.017	0.006	0.013	3.057	.764
2.20	2-12.0	48.40	96.80	145.2	0.039	0.018	0.007	0.013	3.098	.774
2.21	2-12.6	48.80	97.60	146.4	0.040	0.018	0.007	0.013	3.141	.785
2.22	2-13.2	49.30	98.60	147.9	0.041	0.018	0.007	0.014	3.184	.796
2.23	2-13.8	49.70	99.40	149.1	0.042	0.019	0.007	0.014	3.227	.807
2.24	2.14.4	50.20	100.4	150.6	0.043	0.019	0.007	0.014	3.270	.818
2.25	2-15.0	50.60	101.2	151.8	0.044	0.020	0.007	0.014	3.313	.828
2.26	2-15.6	51.10	102.2	153.3	0.045	0.020	0.007	0.015	3.358	.839
2.27	2-16.2	51.50	103.0	154.5	0.046	0.021	0.008	0.015	3.403	.851
2.28	2-16.8	52.00	104.0	156.0	0.047	0.021	0.008	0.016	3.449	.862
2.29	2-17.4	52.40	104.8	157.2	0.048	0.022	0.008	0.016	3.494	.876
2.30	2-18.0	52.90	105.8	158.7	0.049	0.022	0.008	0.016	3.539	.885
2.31	2-18.6	53.40	106.8	160.2	0.050	0.022	0.008	0.017	3.586	.897
2.32	2-19.2	53.80	107.6	161.4	0.051	0.023	0.008	0.017	3.633	.908
2.33	2-19.8	54.30	108.6	162.9	0.052	0.023	0.009	0.017	3.680	.920
2.34	2.20.4	54.80	109.6	164.4	0.053	0.024	0.009	0.018	3.727	.932
2.35	2-21.0	55.20	110.4	165.6	0.054	0.025	0.009	0.018	3.774	.944
2.36	2-21.6	55.70	111.4	167.1	0.056	0.025	0.009	0.019	3.823	.956
2.37	2-22.2	56.20	112.4	168.6	0.057	0.026	0.010	0.019	3.872	.968
2.38	2-22.8	56.60	113.2	169.8	0.058	0.026	0.010	0.019	3.922	.980
2.39	2-23.4	57.10	114.2	171.3	0.059	0.027	0.010	0.020	3.971	.993
2.40	2-24.0	57.60	115.2	172.8	0.060	0.027	0.010	0.020	4.020	1.005
2.41	2-24.6	58.10	116.2	174.3	0.062	0.028	0.010	0.021	4.071	1.018
2.42	2-25.2	58.60	117.2	175.8	0.063	0.028	0.010	0.021	4.123	1.031
2.43	2-25.8	59.00	118.0	177.0	0.064	0.029	0.011	0.021	4.174	1.043
2.44	2-26.4	59.50	119.0	178.5	0.066	0.030	0.011	0.022	4.226	1.056
2.45	2-27.0	60.00	120.0	180.0	0.067	0.030	0.011	0.022	4.277	1.069
2.46	2-27.6	60.50	121.0	181.5	0.069	0.031	0.011	0.023	4.330	1.082
2.47	2-28.2	61.00	122.0	183.0	0.070	0.031	0.012	0.023	4.382	1.095
2.48	2-28.8	61.50	123.0	184.5	0.071	0.032	0.012	0.024	4.437	1.109
2.49	2-29.4	62.00	124.0	186.0	0.073	0.033	0.012	0.024	4.491	1.123
2.50	2-30.0	62.50	125.0	187.5	0.074	0.033	0.012	0.025	4.544	1.136
2.51	2-30.6	63.00	126.0	189.0	0.076	0.034	0.013	0.025	4.600	1.150
2.52	2-31.2	63.50	127.0	190.5	0.077	0.035	0.013	0.026	4.655	1.164
2.53	2-31.8	64.00	128.0	192.0	0.079	0.036	0.013	0.026	4.711	1.178
2.54	2-32.4	64.50	129.0	193.5	0.080	0.036	0.013	0.027	4.766	1.191
2.55	2-33.0	65.00	130.0	195.0	0.082	0.037	0.014	0.027	4.822	1.205
2.56	2-33.6	65.50	131.0	196.5	0.084	0.038	0.014	0.028	4.880	1.220
2.57	2-34.2	66.00	132.0	198.0	0.086	0.039	0.014	0.029	4.938	1.234
2.58	2-34.8	66.60	133.2	199.8	0.088	0.040	0.015	0.029	4.996	1.249
2.59	2-35.4	67.10	134.2	201.3	0.090	0.040	0.015	0.030	5.054	1,263
2.60	2-36.0	67.60	135.2	202.8	0.091	0.041	0.015	0.030	5.112	1.278
2.61	2-36.6	68.10	136.2	204.3	0.093	0.042	0.016	0.031	5.172	1.293
2.62	2-37.2	68.60	137.2	205.8	0.095	0.043	0.016	0.032	5.232	1.308
2.63	2-37.8	69.20	138.4	207.6	0.096	0.043	0.016	0.032	5.292	1.323
2.64	2-38.4	69.70	139.4	209.1	0.098	0.044	0.016	0.033	5,352	1.338
2.65	2-39.0	70.20	140.4	210.6	0.099	0.045	0.017	0.033	5.412	1.353
2.66	2-39.6	70.80	141.6	212.4	0.101	0.045	0.017	0.034	5.474	1.368
2.67	2-40.2	71.30	142.6	213.9	0.103	0.046	0.017	0.034	5.537	1.384
2.68	2-40.8	71.80	143.6	215.4	0.105	0.047	0.017	0.035	5.599	1.400
2.69	2-41.4	72.40	144.8	217.2	0.107	0.048	0.018	0.036	5.662	1.415
2.70	2-42.0	72.90	145.8	218.7	0.109	0.049	0.018	0.036	5.724	1.431
2.71	2-42.6	73.40	146.8	220.2	0.111	0.050	0.018	0.037	5.789	1.447
2.72	2.43.2	74.00	148.0	222.0	0.113	0.051	0.019	0.038	5.854	1.463
2.73	2-43.8	74.50	149.0	223.5	0.116	0.052	0.019	0.039	5.918	1.479
2.74	2-44.4	75.00	150.0	225.0	0.118	0.053	0.020	0.039	5.983	1.496
2.75	2-45.0	75.60	151.2	226.8	0.119	0.054	0.020	0.040	6.048	1.512
2.76	2-45.6	76.20	152.4	228.6	0.122	0.055	0.020	0.041	6.115	1.529
2.77	2-46.2	76.70	153.4	230.1	0.124	0.056	0.021	0.041	6.182	1.545
2.78	2-46.8	77.30	154.6	231.9	0.126	0.057	0.021	0.042	6.250	1.562
2.79	2-47.4	77.80	155.6	233.4	0.129	0.058	0.021	0.043	6.317	1.579
2.80	2-48.0	78.40	156.8	235.2	0.131	0.059	0.022	0.044	6.384	1.596
2.81	2-48.6	79.00	158.0	237.0	0.132	0.060	0.022	0.045	6.453	1.613
2.82	2-49.2	79.50	159.0	238.5	0.136	0.061	0.023	0.045	6.523	1.631
2.83	2-49.8	80.10	160.2	240.3	0.138	0.062	0.023	0.046	6.592	1.648
2.84	2-50.4	80.70	161.4	242.1	0.141	0.063	0.024	0.047	6,662	1.665
2.85	2-51.0	81.20	162.4	243.6	0.143	0.064	0.024	0.048	6.731	1.683
2.86	2-51.6	81.80	163.6	245.4	0.146	0.065	0.024	0.049	6.803	1.701
2.87	2-52.2	82.40	164.8	247.2	0.148	0.066	0.025	0.049	6.875	1.719
2.88	2-52.8	82.90	165.8	248.7	0.151	0.068	0.025	0.050	6.948	1.737
2.89	2-53.4	83.50	167.0	250.5	0.154	0.069	0.026	0.051	7.020	1.755
2.90	2-54.0	84.10	168.2	252.3	0.156	0.070	0.026	0.052	7.092	1.773
2.91	2-54.6	84.70	169.4	254.1	0.159	0.072	0.027	0.053	7.167	1.792
2.92	2-55.2	85.30	170.6	255.3	0.162	0.073	0.027	0.054	7.241	1.810

(Continued on page 262.)

minimum length of tangent 60 ft. between spiral curves of opposite directions.

"The last length of spiral in each column is the maximum to use for the speed at the head of the column. For less speeds use next column to left. The table will be found sufficient for all general cases and any special case can be figured by formula $L = V E$."

Abbreviations.

D_1 = degree of main curve.

D = degree of curve at any point on spiral.

a = rate of change of spiral per station = degree of spiral curve 100 ft. from B. S.

A = deflection in minutes to point on spiral 100 ft. from B. S.

θ = deflection angle at B. S. to any point on spiral.

ϕ = deflection angle at B. M. C. from tangent to the spiral to B. S.

ϕ_1 = deflection angle at B. M. C. from tangent to the spiral to any point on the spiral.

δ = deflection angle from tangent at any point on spiral to B. M. C.

Δ = total angle in spiral at $E = D\ E\ C$. (Fig. 2.)

Δ_1 = angle in first portion of spiral from B. S. to any point on spiral, as from A to B at $G = D\ G\ B$.

Δ_2 = angle in second portion of spiral from any point to B. M. C., as from B to C at F_1.

L = total length of spiral in 100-ft. stations.

d = distance from B. S. to any point on spiral in stations.

d_1 = distance from any point on spiral to B. M. C. in stations.

c = long chord from B. S. to B. M. C., as $A\ C$.

X = distance along tangent to any point as $A\ H$ or $A\ D$.

Y = offset from tangent at any point on spiral as $D\ C$.

U = first tangent of spiral, $A\ E$.

V = second tangent of spiral, $E\ C$.

t = distance from B. S. to point where main curve produced is parallel to tangent as $A\ H$.

T = distance from P. I. to B. S. or E. S. as $I\ A$ or $I\ X$.

E = distance from P. I. to center of main curve.

M = main curve angle.

I = total intersection angle between two main tangents $= M + 2\ \Delta$.

O = offset distance between main tangent and a tangent to main curve produced at H.

Formulas.

When quantities are required for any point on spiral, insert d for L in equations.

$a = 0.269 \surd\ (D_1^3/O) = D_1/L.$

$D = a\ d \quad d = D/a.$

$A = a/6 = D_1/6\,\mathrm{L}.$

$D_1 = a\ L \quad L = D_1/a.$

$\Delta = \frac{1}{2}\ a\ L^2 = \frac{1}{2}\ D_1\ L = D_1^2/2a = 3a\ L^2.$

$\Delta_1 = \frac{1}{2}\ a\ d^2 = \frac{1}{2}\ D\ d.$

$\theta = \frac{1}{3}\ \Delta = \frac{1}{6}\ a\ L^2 = \frac{1}{6}\ D\ L = D^2/6a = A\ L^2.$

$\phi = 2\,\theta$ for whole spiral.

$\phi_1 = A\ d_1\ (3d + 2d_1) = A\ d_1^2\ (3d/d_1 + 2).$

$\delta = A\ d_1\ (3d + d_1) = A\ d_1^2\ (3d/d_1 + 1).$

$\Delta_2 = (\Delta - \Delta_1).$

$Y = 0.2909\ a\ L^3 - .00000158\ a^3\ L^7.$

$X = 100\ L - .000762\ a^2\ L^5$ X Cor. $= .000762\ a^2\ L^5.$

$O = .0727\ a\ L^3 = .0727 \cdot D_1\ L^2 = \frac{1}{4}\ Y.$

$L = 3.714 \surd\ (\sigma/D_1).$

$t = 50\,L - .000127\ a^2\ L^5 = 50\,L - \frac{1}{6}\ X$ Cor.

$c = 100\,L - .00034\ a^2\ L^5$ (in feet).

$U = X - Y \cot \Delta = X - V \cos \Delta = \frac{2}{3}\ L + \frac{1}{3}\ X$ Cor.

$$V = \frac{Y}{\sin \Delta} = \frac{100}{3}\ L + .000244\ a^2\ L^5 = \frac{1}{3}\ L + \frac{1}{3}\ X \text{ Cor.}$$

$T = t + (R + o) \tan \frac{1}{2}\ I.$

UNIT TABLE FOR TALBOT'S SPIRAL.—Continued.

L in 100 ft. Stations.	D Deg. and Min.	Θ Min.	φ Min.	Δ Min.	X Cor. Minus.	C Cor. Minus.	t Cor. Minus.	U & V Cor. Plus.	Y Ft.	O Ft.
2.93	2-55.8	85.80	171.6	257.4	0.164	0.074	0.027	0.055	7.316	1.829
2.94	2-56.4	86.40	172.8	259.2	0.167	0.075	0.028	0.056	7.390	1.848
2.95	2-57.0	87.00	174.0	261.0	0.170	0.077	0.028	0.057	7.465	1.866
2.96	2-57.6	87.60	175.2	262.8	0.173	0.078	0.029	0.058	7.542	1.886
2.97	2-58.2	88.20	176.4	264.6	0.176	0.079	0.029	0.059	7.619	1.905
2.98	2-58.8	88.80	177.6	266.4	0.179	0.080	0.030	0.060	7.696	1.924
2.99	2-59.4	89.40	178.8	268.2	0.182	0.081	0.030	0.061	7.773	1.943
3.00	3-00.0	90.00	180.0	270.0	0.185	0.083	0.031	0.062	7.850	1.962
3.01	3-00.6	90.60	181.2	271.8	0.188	0.085	0.031	0.063	7.930	1.982
3.02	3-01.2	91.20	182.4	273.6	0.191	0.086	0.032	0.064	8.010	2.002
3.03	3-01.8	91.80	183.6	275.4	0.195	0.087	0.032	0.065	8.090	2.022
3.04	3-02.4	92.40	184.8	277.2	0.198	0.088	0.033	0.066	8.170	2.043
3.05	3-03.0	93.00	186.0	279.0	0.201	0.090	0.034	0.067	8.250	2.063
3.06	3-03.6	93.60	187.2	280.8	0.204	0.092	0.034	0.068	8.332	2.083
3.07	3-04.2	94.20	188.4	282.6	0.208	0.094	0.035	0.069	8.415	2.104
3.08	3-04.8	94.80	189.6	283.8	0.211	0.095	0.035	0.070	8.497	2.124
3.09	3-05.4	95.50	191.0	286.5	0.215	0.097	0.036	0.072	8.580	2.145
3.10	3-06.0	96.10	192.2	288.3	0.218	0.098	0.036	0.073	8.662	2.165
3.11	3-06.6	96.70	193.4	290.1	0.222	0.100	0.037	0.074	8.747	2.187
3.12	3-07.2	97.30	194.6	291.9	0.225	0.101	0.037	0.075	8.832	2.208
3.13	3-07.8	98.00	196.0	294.0	0.229	0.103	0.038	0.076	8.917	2.229
3.14	3-08.4	98.60	197.2	295.8	0.232	0.104	0.039	0.077	9.002	2.250
3.15	3-09.0	99.20	198.4	297.6	0.236	0.106	0.039	0.079	9.087	2.272
3.16	3-09.6	99.9	199.8	299.7	0.240	0.108	0.040	0.080	9.175	2.294
3.17	3-10.2	100.5	201.0	301.5	0.244	0.110	0.041	0.081	9.263	2.316
3.18	3-10.8	101.1	202.2	303.3	0.248	0.112	0.041	0.083	9.351	2.338
3.19	3-11.4	101.8	203.6	305.4	0.252	0.113	0.042	0.084	9.438	2.379
3.20	3-12.0	102.4	204.8	307.2	0.255	0.115	0.043	0.085	9.526	2.382
3.21	3-12.6	103.0	206.0	309.0	0.260	0.117	0.043	0.087	9.616	2.404
3.22	3-13.2	103.7	207.4	311.1	0.264	0.119	0.044	0.088	9.706	2.426
3.23	3-13.8	104.3	208.6	312.9	0.268	0.121	0.045	0.089	9.797	2.449
3.24	3-14.4	105.0	210.0	315.0	0.272	0.122	0.045	0.091	9.887	2.472
3.25	3-15.0	105.6	211.2	316.8	0.276	0.124	0.046	0.092	9.978	2.494
3.26	3-15.6	106.3	212.6	318.9	0.280	0.126	0.047	0.093	10.071	2.518
3.27	3-16.2	106.9	213.8	320.7	0.285	0.128	0.047	0.095	10.164	2.541
3.28	3-16.8	107.6	215.2	322.8	0.289	0.130	0.048	0.096	10.258	2.564
3.29	3-17.4	108.2	216.4	324.6	0.294	0.132	0.049	0.098	10.351	2.588
3.30	3-18.0	108.9	217.8	326.7	0.298	0.134	0.050	0.099	10.446	2.611
3.31	3-18.6	109.6	219.2	328.8	0.303	0.136	0.051	0.101	10.541	2.635
3.32	3-19.2	110.2	220.4	330.6	0.307	0.138	0.051	0.102	10.637	2.659
3.33	3-19.8	110.9	221.8	332.7	0.312	0.140	0.052	0.103	10.734	2.683
3.34	3-20.4	111.6	223.2	334.8	0.316	0.142	0.053	0.105	10.831	2.708
3.35	3-21.0	112.2	224.4	336.6	0.321	0.144	0.053	0.107	10.928	2.732
3.36	3-21.6	113.0	226.0	339.0	0.326	0.147	0.054	0.109	11.026	2.757
3.37	3-22.2	113.6	227.2	340.8	0.331	0.149	0.055	0.110	11.125	2.781
3.38	3-22.8	114.2	228.4	342.6	0.336	0.151	0.056	0.112	11.224	2.806
3.39	3-23.4	114.9	229.8	344.7	0.341	0.154	0.057	0.113	11.324	2.831
3.40	3-24.0	115.6	231.2	346.8	0.346	0.156	0.058	0.115	11.425	2.856
3.41	3-24.6	116.3	232.6	348.9	0.351	0.158	0.059	0.117	11.525	2.881
3.42	3-25.2	117.0	234.0	351.0	0.356	0.160	0.059	0.119	11.628	2.907
3.43	3-25.8	117.6	235.2	352.8	0.362	0.163	0.060	0.121	11.729	2.932
3.44	3-26.4	118.3	236.6	354.9	0.367	0.165	0.061	0.122	11.832	2.958
3.45	3-27.0	119.0	238.0	357.0	0.372	0.167	0.062	0.124	11.938	2.984
3.46	3-27.6	119.7	239.4	359.1	0.378	0.170	0.063	0.126	12.039	3.010
3.47	3-28.2	120.4	240.8	361.2	0.383	0.172	0.064	0.128	12.144	3.036
3.48	3-28.8	121.1	242.2	363.3	0.389	0.175	0.065	0.130	12.249	3.082
3.49	3-29.4	121.8	243.6	365.4	0.394	0.177	0.066	0.131	12.355	3.089
3.50	3-30.0	122.5	245.0	367.5	0.400	0.180	0.067	0.133	12.461	3.115
3.51	3-30.6	123.2	246.4	369.6	0.406	0.183	0.068	0.135	12.567	3.142
3.52	3-31.2	123.9	247.8	371.7	0.412	0.185	0.069	0.137	12.676	3.169
3.53	3-31.8	124.6	249.2	373.8	0.418	0.188	0.070	0.139	12.784	3.196
3.54	3-32.4	125.3	250.6	375.9	0.423	0.190	0.071	0.141	12.893	3.223
3.55	3-33.0	126.0	252.0	378.0	0.429	0.193	0.072	0.143	13.002	3.251
3.56	3-33.6	126.7	253.4	380.1	.0436	0.196	0.073	0.145	13.112	3.278
3.57	3-34.2	127.4	254.8	382.2	0.442	0.199	0.074	0.147	13.225	3.306
3.58	3-34.8	128.2	256.4	384.6	0.448	0.202	0.075	0.149	13.334	3.333
3.59	3-35.4	128.9	257.8	386.7	0.454	0.204	0.076	0.151	13.446	3.361
3.60	3-36.0	129.6	259.2	388.8	0.460	0.207	0.077	0.153	13.558	3.389
3.61	3-36.6	130.3	260.6	390.9	0.467	0.210	0.078	0.156	13.672	3.418
3.62	3-37.2	131.0	262.0	393.0	0.474	0.213	0.079	0.158	13.785	3.446
3.63	3-37.8	131.8	263.6	395.4	0.480	0.216	0.080	0.160	13.909	3.477
3.64	3-38.4	132.5	265.0	397.5	0.487	0.219	0.081	0.162	14.015	3.504
3.65	3-39.0	133.2	266.2	399.6	0.493	0.222	0.082	0.164	14.132	3.533
3.66	3-39.6	134.0	268.0	402.0	0.500	0.225	0.083	0.167	14.248	3.562
3.67	3-40.2	134.7	269.4	404.1	0.507	0.229	0.084	0.169	14.366	3.591
3.68	3-40.8	135.4	270.8	406.2	0.514	0.232	0.086	0.171	14.483	3.621
3.69	3-41.4	136.2	272.4	408.6	0.521	0.235	0.087	0.174	14.602	3.650
3.70	3-42.0	136.9	273.8	410.7	0.528	0.238	0.088	0.176	14.720	3.680
3.71	3-42.6	137.6	275.2	412.8	0.535	0.241	0.089	0.178	14.840	3.710
3.72	3-43.2	138.4	276.8	415.2	0.543	0.244	0.090	0.181	14.960	3.740
3.73	3-43.8	139.1	278.2	417.3	0.550	0.247	0.092	0.183	15.081	3.770
3.74	3-44.4	139.9	279.8	419.7	0.557	0.251	0.093	0.186	15.202	3.800
3.75	3-45.0	140.6	281.2	421.8	0.564	0.254	0.094	0.188	15.324	3.831
3.76	3-45.6	141.4	282.8	424.2	0.572	0.257	0.096	0.191	15.446	3.861
3.77	3-46.2	142.1	284.2	426.3	0.580	0.261	0.097	0.193	15.570	3.892
3.78	3-46.8	142.9	285.8	428.7	0.588	0.265	0.098	0.196	15.695	3.924
3.79	3-47.4	143.6	287.2	430.8	0.596	0.268	0.099	0.199	15.819	3.955
3.80	3-48.0	144.4	288.8	433.2	0.604	0.271	0.100	0.201	15.944	3.986
3.81	3-48.6	145.2	290.4	435.6	0.612	0.275	0.102	0.204	16.071	4.018
3.82	3-49.2	145.9	291.8	437.7	0.620	0.279	0.103	0.207	16.197	4.049
3.83	3-49.8	146.7	293.4	440.1	0.628	0.283	0.105	0.209	16.324	4.081
3.84	3-50.4	147.5	295.0	442.5	0.636	0.286	0.106	0.212	16.453	4.113
3.85	3-51.0	148.2	296.4	444.6	0.644	0.290	0.107	0.215	16.581	4.145
3.86	3-51.6	149.0	298.0	447.0	0.653	0.294	0.109	0.217	16.711	4.178
3.87	3-52.2	149.8	299.6	449.4	0.661	0.297	0.110	0.220	16.840	4.210
3.88	3-52.8	150.5	301.0	451.5	0.670	0.301	0.112	0.223	16.971	4.243
3.89	3-53.4	151.3	302.6	453.9	0.678	0.305	0.113	0.226	17.103	4.276
3.90	3-54.0	152.1	304.2	456.3	0.687	0.309	0.115	0.229	17.234	4.308
3.91	3-54.6	152.9	305.8	458.7	0.696	0.314	0.116	0.232	17.367	4.342
3.92	3-55.2	153.7	307.4	461.1	0.705	0.318	0.117	0.235	17.500	4.375
3.93	3-55.8	154.4	308.8	463.2	0.714	0.322	0.119	0.238	17.634	4.408
3.94	3-56.4	155.2	310.4	465.6	0.723	0.326	0.120	0.241	17.769	4.442
3.95	3-57.0	156.0	312.0	468.0	0.732	0.330	0.122	0.244	17.904	4.476
3.96	3-57.6	156.8	313.6	470.4	0.742	0.334	0.123	0.247	18.041	4.510
3.97	3-58.2	157.6	315.2	472.8	0.751	0.338	0.125	0.251	18.178	4.544
3.98	3-58.8	158.4	316.8	475.2	0.760	0.342	0.127	0.253	18.315	4.579
3.99	3-59.4	159.2	318.4	477.6	0.770	0.346	0.128	0.257	18.453	4.613
4.00	4-00.0	160.0	320.0	480.0	0.780	0.351	0.130	0.260	18.592	4.648

Forests and Run-Off.

It is a matter of dispute whether the removal of forests always affects the amount of run-off from watersheds, for records of certain European districts indicate that deforestation has not been followed by increased floods and erosion of the soil. In examining the subject in detail, however, it has been observed repeatedly that where the removal of the forests has been followed by agricultural work which opens up the pores of the soil, assuming the latter to be somewhat coarse grained, the run-off and soil erosion may not be materially affected. This relation of forests and agriculture to run-off and soil erosion is pointed out in an exhaustive bulletin on the Potomac River basin recently issued by the U. S. Geological Survey, from which the following notes are taken.

If the rain-fall is all absorbed, as by a coarse, sandy soil, there is no run-off and no erosion. As the soil becomes finer in texture, more compact, and correspondingly less pervious, the rain is not absorbed as fast as it falls. The impact of the raindrops loosens the fine particles of soil, and unless absorption takes place the drops gather into small streams and rivulets, transporting with them, by a system of natural elutriation, the finest particles of soil and leaving behind the larger and heavier grains. At first this is entirely due to the hydraulic action of the impinging raindrops, but no sooner do the rivulets gather power, either by the added volume of water or by increased gradient, than they likewise begin cutting loose and transporting the soil.

The capacity of a stiff soil for water is in practice 35 to 50 per cent. of its volume, or for ordinary farmed soils 4 to 5 inches of rainfall to the surface foot. In spite of this capacity, the greater part of a heavy shower will usually not be absorbed. The coarse structure of a sandy soil permits the rainfall to be absorbed as rapidly as it falls. In a clay soil, unless in a high state of tilth, the pores are smaller and there is less open cellular communication between them, and absorption must largely take place through cracks, worm holes, and root holes, and when there are few of these absorption is largely retarded until the air can be expelled.* In the extreme case, that of a raw clay soil with its surface puddled by a previous heavy rain, the result is, as King points out, "that when a heavy rain falls, the close structure and feeble granulation result in the surface pores of the soil becoming so quickly closed that the soil air has little opportunity to escape, and yet only so fast as it does escape can rain enter the soil, and hence during heavy rains the water accumulates quickly and extensively upon the surface."

The greater portion of the tilled soils of the Potomac basin, especially of the lower part, are of heavy type and close texture, and the run-off from them indicates failure to absorb. But were they well granulated and in good tilth they, as well as the more permeable sandy soils, could readily absorb, without undue accumulation of surface water, a much heavier rain than commonly falls at one time on the Potomac basin.

The porous condition or granulation of a heavy soil necessary to effect absorption is best procured by the addition of humus.

There is room for a large storage of storm water in farming soils, and more rational farming methods must ultimately lead to this. The effect of such storage would be reflected in a diminished run-off of flood water, especially of heavy midsummer rains. Little of the water thus accumulated would normally pass off as seepage to spring and river flow. The improved growth of the crops would utilize such stored water, and give a more constant and available amount of soil moisture.

Any additional storage, either transient, tending to prolong or distribute a flood crest, or deep seated, tending to increase the amount of the dry-season flow, can be secured only in the forest soil. Storage in forest soil, except in sandy phases, takes place very largely through the medium of humus. The amount of water which is actually retained by a thin humus is small, in fact, a thin humus is usually far more litter than humus and has a very low retentive capacity; but the chief function of humus, except where it has accumulated to a great depth, are (1) to maintain the volume and depth of the soil by preventing erosion; (2) to secure the porosity of the soil; (3) to promote the absorption of rainfall by the soil in retarding the run-off of heavy showers until the water can be absorbed, as the air is gradually expelled from the soil; (4) to act as a mulch and lessen the evaporation of soil moisture.

On coarse, deep sands of low gradient the office of humus is at a minimum. There is no surface flow of storm water and no soil transportation; evaporation of soil moisture is low both from the surface of the soil and from transpiration by the xerophytic flora, and the larger part of the rainfall passes as percolation. With an increase in the clay component, greater radient, and a decrease in soil depth, humus becomes more essential in supplementing the water-absorbing and water-carrying capacity of the soil, its functions in this respect attaining a maximum on heavy, shallow clays of mountain slopes.

Where the humus is thick, however, it possesses a high storage capacity. While there is some doubt in regard to the exact amount of water humus is capable of holding, the quantity is relatively large. The lowest estimates by Ebermayer place it at considerably more than its own weight, and Wiley's investigations of Florida mucks give it about the same capacity, while Wollny places it at about four times its weight, and Henry's laboratory experiments tend to confirm Wollny's high limit. The capacity of humus must vary, however, not only with the state of decomposition, but with its origin as well, since the pore space is the final determinant of its water-bearing capacity. The undecomposed litter, which covers the humus and from which humus is formed, does not exhibit the characters of humus toward water. It protects the humus, as humus does the underlying soil, from excessive transportation by surface water and in addition from excessive evaporation, acting as a mulch.

The accumulation of humus on forest soil depends, if it has neither been disturbed nor destroyed, on the kind of species forming the forest and to some extent on the soil, the destruction of humus proceeding rapidly on loose, porous soils, which permit freer circulation of air and afford the condition best suited for bacteriological activity, and since many species of trees, especially the white oak and chestnut, have a wide range of soil adaptability, their capacity to accumulate humus is modified both by their rate of growth on the soil and by the oxidizing capacity of the soal on which they happen to be growing.

THE BOSPHORUS BRIDGE linking Europe to Asia is a project that Sultan Abdul Hamed has long had under consideration. The last bridge was that built by Darius for the use of his army long before the Christian era. The plans for the Turkish bridge were accepted years ago and call for short suspension spans between a succession of granite towers, of which the foundations are now being built.

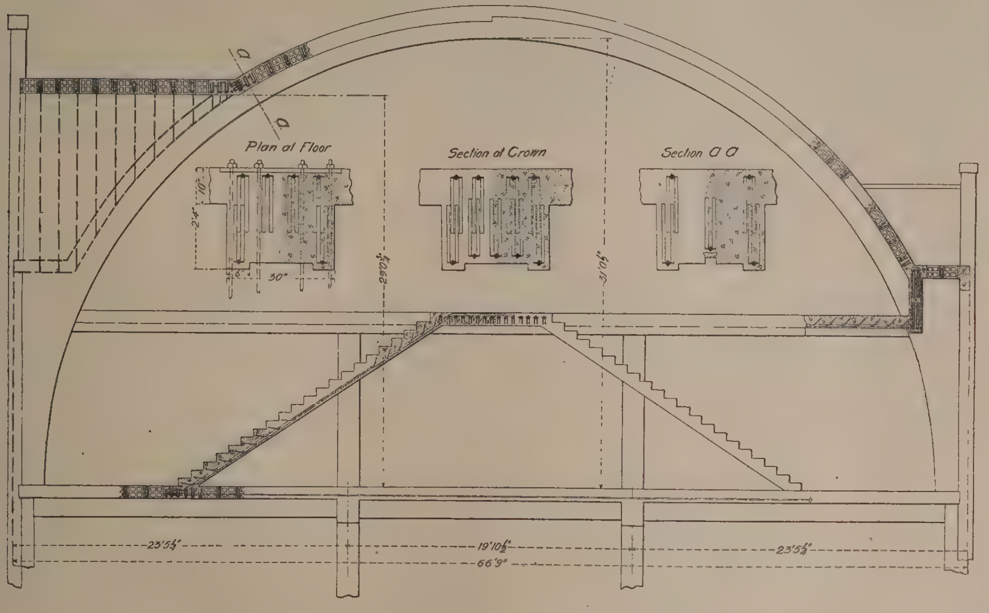
The New Manufacturing Plant of the George N. Pierce Co., Buffalo, N. Y.

By Howard S. Knowlton.

One of the latest industrial plants to be completed in Buffalo is the new automobile manufacturing establishment of the George N. Pierce Co., located on the site of the Pan-American Exposition grounds. The company employs about 1,600 men, and it has been building the well-known Great Arrow car. The group of buildings which comprise the plant are all of reinforced concrete, the engineers and architects for the work being Messrs. Lockwood, Greene & Co., of Boston, with Mr. Albert Kahn, of Detroit, as associate architect. The designs and plans for the reinforced concrete work were made by the Trussed Concrete Steel Co. The office or so-called "welfare building" was designed by Mr. George Cary, of Buffalo.

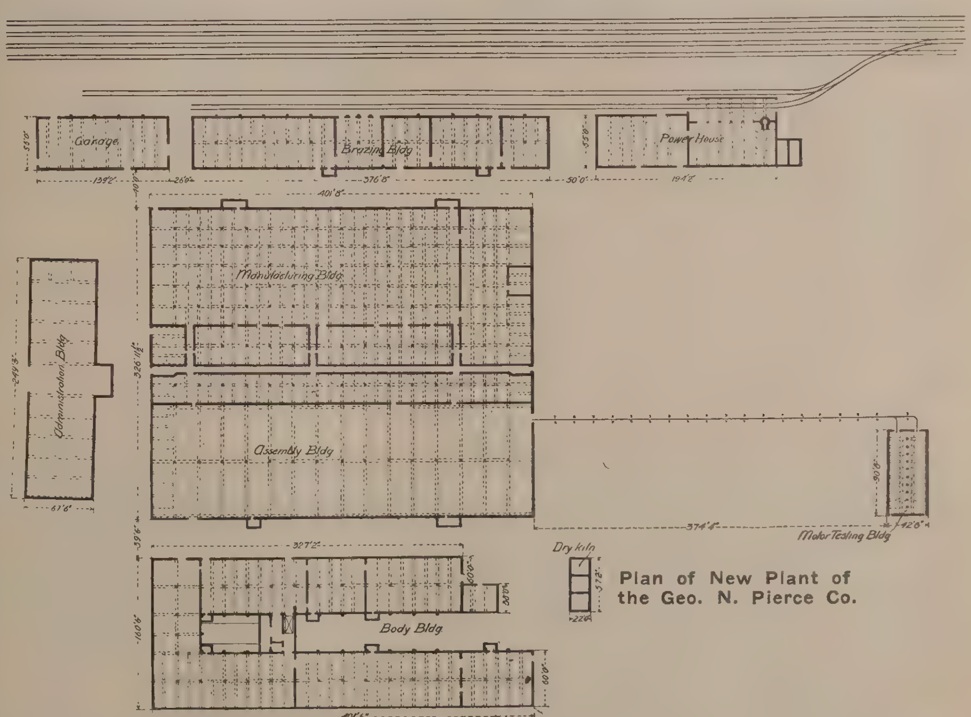
Administration Building.—The plant occupies part of a lot of land fronting on Elmwood Ave., and is located beside the New York Central & Hudson River R. R. with special siding facilities for the receipt of materials and the shipment of products. The area of the property is about 15 acres, the lot being nearly rectangular, 997.3 ft. long and 655.2 ft. wide. There are eight buildings in the establishment at present. At the Elmwood Ave. entrance of the works, near the centre of the property, stands the Administration or Welfare Building, which is about 252 ft. long by 70 ft. wide, and three stories in height, with a barrel-arch roof. This building is the main entrance to every department of the plant. In the basement are provided lockers, bicycle and wash rooms for the employees, and from this basement the main manufacturing building is reached by underground passages. On the first floor are located the administrative and general offices of the company with a club room for department heads. The second floor is devoted to welfare work and its principal feature is a large restaurant for the use of employees.

The unique feature of the building is the barrel roof, carried by arches spaced 30 ft. on centres at the end spans and 20 ft. for all other spans. The ribs are approximately 30 in. wide by 26 in. deep, and are reinforced by nine 1¼x3¾-in. Kahn bars, five in the intrados and four in the extrados, at the crown. Four 1⅛-in. round rods run between the springing lines of the arches imbedded in the second floor. The roof slabs are made of 10-in. hollow tile spaced 16 in. on centres, with a 4-in. concrete joist between each row of tile. The joist has a ¾x2-in. Kahn bar as reinforcement. The first and second floors are of somewhat similar construction.



Cross Section of Administration Building.

Shops.—In the rear of the Administration Building are the main shops. These are composed of the Body Building, about 401½x160½ ft.; the Manufacturing Building, about 327x402¾ ft.; the garage, 139¼x55 ft.; the Brazing Building, 376¾x55 ft., and the power house, 194¼x55 ft. There are also a 22x57½-ft. dry kiln, a gas house 26 ft. square, and a motor-testing building, measuring 90¾x42¾ ft. The last is located 374 ft. from the nearest shop to allow for the extension of the works to meet future business requirements.

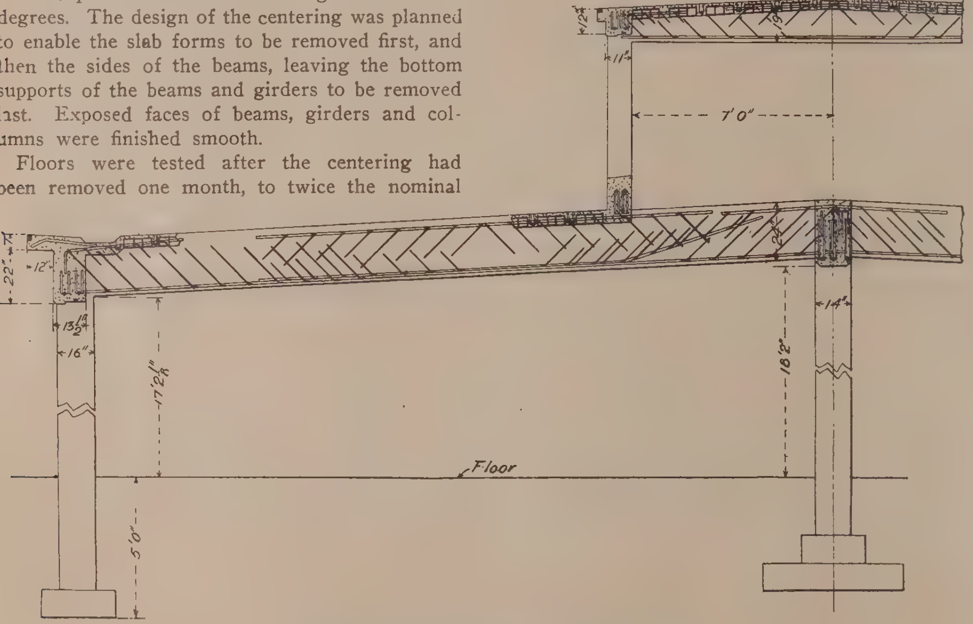


Plan of New Plant of the Geo. N. Pierce Co.

The Body Building is two stories in height, and divided by brick firewalls into the various storage and fitting, paint, lumber, filing, gluing, varnishing, trimming, pattern and blacksmith shops necessary in the production of the automobile body. The manufacturing building is one story in height and contains stores, tool, inspection, machine shop, experimental and assembly divisions. The assembly department is located on the side of the building nearest the Body Building and is 402¾x122 ft. It is separated by a brick fire wall from the main manufacturing section. The Brazing Building includes in its single story brazing and tin shops, sand blast, case hardening, nickel plating, chip and receiving rooms. The power house has a coal pocket, boiler room, compressor and pump room, and an engine room. The side tracks have an aggregate length of 2,115 ft., and are three in number. One serves the coal pocket, and the other two serve the engine room, brazing building, and garage. The total floor space in the plant aggregates 280,000 sq. ft. Ground was broken on April 23, 1906, and the last building was turned over to the owners in November.

General Details.—All supported floors and roofs in the plant are built of hollow tile and reinforced concrete on the Kahn system. The beams, columns, footings and stairs are of concrete-steel. The concrete is composed of one part Portland cement, two of sand and four of crushed stone. The stone for footings was not allowed to exceed 2 in. in size, and for all other work ½-in. standard hard burned tile grooved on all sides, was used, and the concrete was all machine mixed. The concrete was designed to resist direct compression and shear up to 30 lb. per square inch. The minimum thickness of the concrete covering on the steel at any point is 1 in. The maximum elastic limit allowed in the steel was 45,000 lbs. per square inch, and the tensile strength of the steel was specified at a minimum of 60,000 lb. with 20 per cent. elongation in 8 in. test pieces. The cold bending test was 180 degrees. The design of the centering was planned to enable the slab forms to be removed first, and then the sides of the beams, leaving the bottom supports of the beams and girders to be removed last. Exposed faces of beams, girders and columns were finished smooth.

Floors were tested after the centering had been removed one month, to twice the nominal safe live load, uniformly distributed over the panels. The maximum specified deflection allowed was 1/400th part of the span, with return to normal position after removal of the load. The reinforced concrete work was designed for the following unit stresses: For hooped or latticed columns of concrete, 750 lbs.; shearing stresses in concrete and adhesion of concrete to steel, 30 lbs.; beams, slabs and girders in direct compression, 500 lbs.; tensile stress in steel, 16,000 lbs.; compression in steel, 12,000 lbs. The tensile strength of the concrete was not considered, and the ratio of the moduli of elasticity of concrete and steel was 1:12.

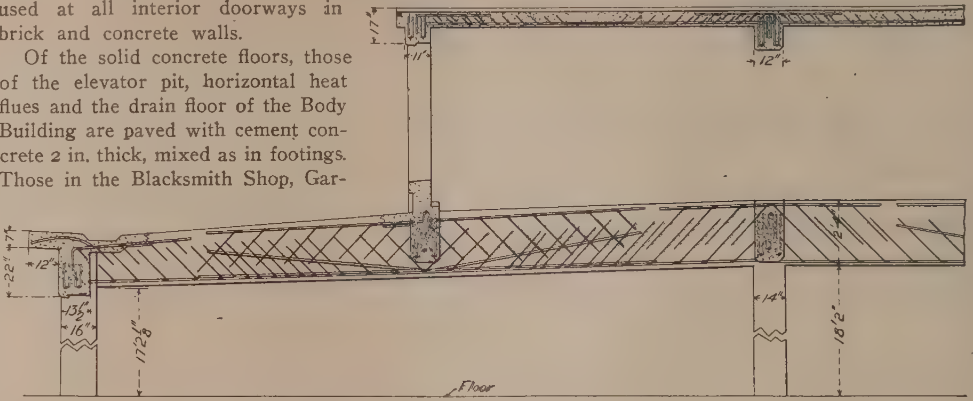


Transverse Section of Brazing Building.

Girders and beams were designed with top reinforcement over the bearing to provide for continuous girder action; and the diameter of columns was taken at a minimum of one-sixteenth the total height. Footings were built of 1:3:6 concrete, and were laid in 5 in. layers, each layer being started before the previous one had commenced to set. The foundation walls were built of concrete mixed in the same proportions as for footings.

Brickwork was employed in various interior walls, all fire walls being thus made; in the walls of buildings, where the spaces between columns are not occupied by windows; for certain footings, and in filling in the gaps between adjacent windows and the horizontal reinforced concrete wall columns. The tunnel from the power house to the Body and Manufacturing Buildings is provided with walls and roofs of reinforced concrete, the floor being plain concrete. Window sills are reinforced, and in the floor of the garage are built pits with sides and bottoms of cement concrete. Cast iron sills are used at all interior doorways in brick and concrete walls.

Of the solid concrete floors, those of the elevator pit, horizontal heat flues and the drain floor of the Body Building are paved with cement concrete 2 in. thick, mixed as in footings. Those in the Blacksmith Shop, Garage and Brazing Building are laid with a 5 or 6-in. base of cement concrete and a 1 in. wearing surface of Portland cement mortar. The floor of the Testing Building is laid with a 3½-in. cement concrete base, with a 1-in. Portland cement mortar wearing surface. The roof of the Body Building is covered with dry cinders, with a top layer of 1-in. concrete, drained to sumps formed in the latter. Earth floors were used in pipe pits. Water-closet floors are reinforced concrete covered with rock asphalt ⅞ in. thick. Tar concrete floors 4 in. thick are used in the first story of buildings with plank wearing courses.



Longitudinal Section of Brazing Building.

Partitions in the Manufacturing, Garage and Brazing Buildings are of metal and plaster, 2 in. thick, braced with 3-in. channels running to the beams, and one side of the studding is covered with steel lath and plastered. Where hollow tile partitions are used, the tile are laid in 1:3 cement mortar, the tiles being wet. The under sides of all hollow tile floors and roofs are plastered with two coats of cement mortar.

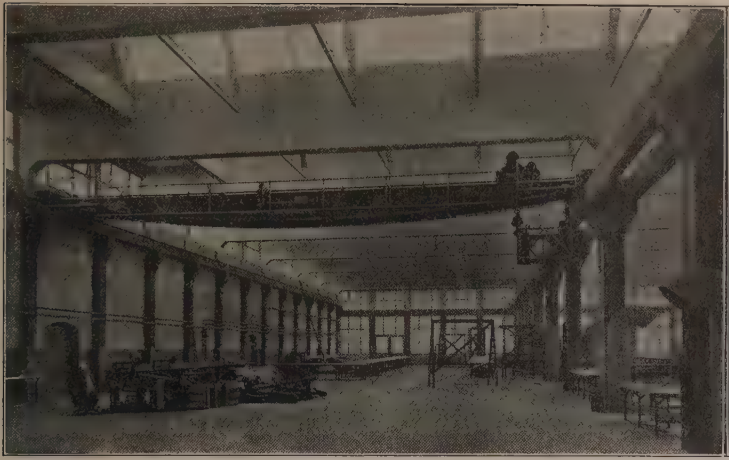
The entire skylights, except the ends and space occupied by the sash are of reinforced concrete. The ends are hollow tile, and the fronts have wood frames anchored to the concrete for securing the sash. The sashes are of 2¼ in. cypress stock, and are glazed on the outside with ¼ in. ribbed glass in one length and on the inside with clear glass. The concrete work in front and the tile work at the ends are covered with 16 oz. copper. The roof, columns and beams of monitors on the Blacksmith, Garage and Brazing Buildings are reinforced concrete and the monitor sashes are glazed with ½-in. ribbed glass. The skylights over the Testing Building and the sand blast rooms in the Brazing Building are framed with heavy galvanized iron with condensation gutters which discharge on the roof. These are glazed with ¼-in. plate glass 18 in. wide. The backs of all saw tooth skylights and roofs are covered with five-ply asphalt and slag roofing.

Brazing Building.—The Brazing Building is designed with a single row of columns, one every 25 ft. This is considered to give the most economical arrangement, because of the wide spacing of columns affords large unbroken floor areas. Because of the necessity of good ventilation this building is built with a monitor its entire length. Sashes 13 ft. 4 in. high on each side of the monitor give a quick means of ventilating the entire building.

The transverse beams in this building are 12x24 in., reinforced with two 1¼x3¾ in. bars and one ¾x2-in. bar. One 1x3-in. compression bar is also used. The top continuity bars over the supports are 1x3 in. The main horizontal girders are 14x28 in. reinforced with three 1¼x3¾ in. and two ¾-in.x2-in. bars. As these girders were not of T section, it was deemed necessary to put in two 1x3 in. compression bars and also a 1x3 in. continuity bar over all columns. The transverse beams are supported alternately on columns and by the longitudinal girder. The interior columns are 14x14 in., reinforced with four ¾x2 in. bars. The exterior columns are 16x16 in., being made that size for architectural effect. The corners of all columns and beams are chamfered.

The roof of this building is constructed of 4-in. tile 16 in. apart on centres, with 4 in. concrete joists between the tile courses. Each course is reinforced with a ½x1½ in. Kahn bar. One inch of concrete is spread over the tile in order to give a fastening for the waterproof roofing.

Manufacturing Building.—In the Manufacturing Building the columns are spaced 25 ft. apart lengthwise and 20½ ft. 6 in. crosswise. The minimum headroom from the finished floor to the under side of the beams is 16½ ft. The saw-tooth skylight beams are spaced every 12½ ft., one coming over every column and one midway between columns, with a 4-in. tile slab rein-



An Aisle in the Assembly Building.

Manufacturing and Assembly Buildings.

forced with ½x1½ in. bars. The inclined beams are reinforced with two 1x3 in. bars and one compression bar, together with the top reinforcing bars. The pitch of the roof is about 30 degrees, while the windows are inclined at an angle of 60 degrees.

In order to carry the large amount of shafting and machinery in this building, a system of 8-in. I-beams is used, spaced 8 ft. 4 in. apart on centres. A stiffening is run from the roof to the centre of each I-beam to prevent vibration. The construction of the roof itself depends in no way upon these steel beams, which are put in only to facilitate hanging shafting.

The main girders of this building have 25 ft. span and are 14x26 in. reinforced with two 1¼x3¾-in. and one 1x3-in. bars and two ¾-in.x2-in. compression bars. In all valleys of the roof of this building, concrete saddles were formed to provide for the drainage, the downspouts being approximately 50 ft. apart. The columns are 14x14-in., reinforced with four ¾x2-in. bars.

This building is at the present time filled with machine tools of every description, most of them to be used for turning out small pieces of work requiring careful execution and inspection. The employees prefer to work in the interior of the building rather than at the wall benches, as the light is better and more constant 200 ft. away from the walls than it is next the outside windows.

Assembly Building.—The Assembly Building section is divided in the centre by a row of 24x24-in. columns. Two 3-ton cranes travel the full length of the building, and the single row of columns was arranged to give these a large area of action. These are two bays 62 ft. wide and 401 ft. long, so the sawtooth construction was faced east, and the 62 ft. span taken care of by a reinforced concrete girder 16x84-in. in section.

The crane girders are reinforced concrete throughout, no steel beams of any description being used. The girders fastened to the centre row of columns span 25 ft. and are 12x22 in., reinforced with 1x3-in. bars, together with a compression bar and a top reinforcing bar at every column. The rails are fastened directly into the concrete, ⅝-in. bolts being used, which together with iron clamps used to hold the rail in position, are bedded in the concrete. The crane girders in the sides of the building are 12x16 in., reinforced with two ⅜x2 in. bars and one 1x3-in. bar, together with one ¾-in. compression bar and one ¾-in. top reinforcing bar. These girders are designed to carry a 5.5-ton wheel load on a 10-ft. wheel base. In tests recently made a centre load of 28,000 lbs. was placed on one of the beams, and a deflection of a scant 1/16 in. resulted.

The centre row of columns in this building are 24x24 in., reinforced with four 1x3 in. Kahn bars, and four 1¼x3¾ in. unsheared Kahn bars. Owing to the necessity of having proper clearance for the cranes, brackets have been provided on these columns where the crane girders are attached.

For all outside windows ⅛ in. ribbed glass was used. The lower and upper sashes are provided with Taber fixtures, which permit the windows to swing out and also to be raised and lowered. About ten sashes are operated from a point.

Body Building.—The floors of the Body Building are designed to carry a live load of 150 lbs. per square foot. The roof is designed and built as strong as the second floor so that another story can be added at any time. The pitch of the roof is furnished by cinder fills. Each wing is arranged with a row of columns down the centre longitudinally, a column occurring every 25 ft. The floor slab, which has a span of 12 ft. 6 in., is composed of 10 in. hollow tile 16 in. on centres between 4 in. concrete joists reinforced with one ½x1½-in. bar. The cross beams carrying this floor are 14x30 in., reinforced with three 1¼x3¾-in. and two 3¾x2-in. bars. One 1x3-in. compression bar is also necessary. Every other beams rests on the columns while the beams between the supported at the centre of the longitudinal girder. Longitudinal girders are 18x36 in., reinforced with five 1¼x3¾-in. and two ¾-in.x2-in. sheared bars, and three ¾x2-in. unsheared bars.

The centre row of columns in each wing in this building are 24x24 in., carrying the second floor, and 20x20 in., carrying the roof or future third floor. The reinforcement of the lower columns is four 1¼x3¾-in. and four ¾x2-in. Kahn bars and four 1x3-in. unsheared bars. The columns above are reinforced with four 1x3-in. sheared bars and four 1x3-in. unsheared bars.

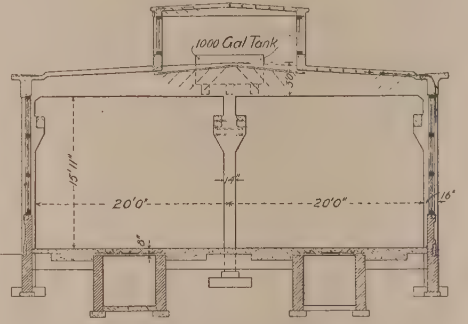
The footings for this row of columns demonstrate the elasticity of the application of rein-

First Floor of the Body Building.

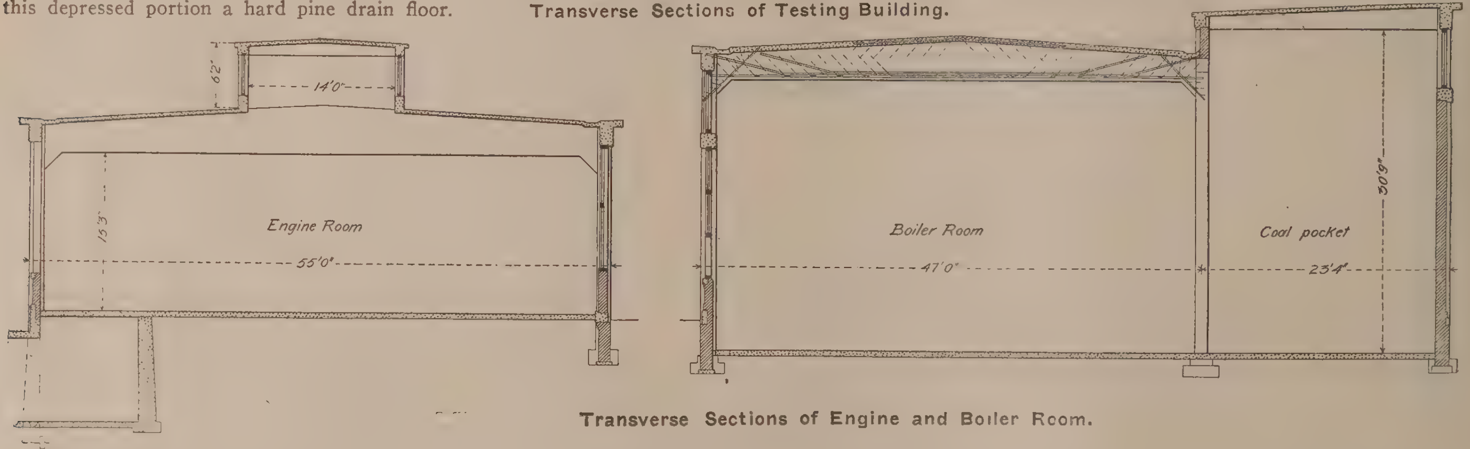
Shafting-Supports in Manufacturing Building.

forced concrete design. Figuring this footing as carrying two floors and the roof, a size of 12 ft. 6 in.x12 ft. 6 in.x30 in. deep, reinforced with 28—1x3-in. bars is necessary. The columns rest directly on a small cap 3 ft. 4 in. x 3 ft. 4 in. x 18 in. thick. Owing to the way in which the property previously had been cut up by the Pan-American Exposition, and also because of the poor quality of the clay, it was necessary to design the footings of all buildings at a very low bearing value, averaging between 3,000 and 4,000 lbs. per square foot. In many cases, owing to the way in which the ground was broken up by old foundations, sewers and other works, it was necessary to make a great many changes in the footings. With reinforced concrete this was very easy to do, as bad portions of the ground could be arched over or beams put in, spanning the weak spots. In many cases the outside curtain walls are not carried on a footing of their own, but a reinforced concrete sill was put in, and the walls carried on this. A great deal of time and expense was saved in this way, as in some cases it would have been necessary to go down 10 or 12 ft. below grade for proper footings.

In one section of the second floor it was found desirable to construct a slatted platform at the same level as the finished floor, so that the unfinished bodies could be placed on this portion and washed down. This was arranged by dropping the concrete slab a little, making it flush with the ceiling below and building over this depressed portion a hard pine drain floor.



Transverse Sections of Testing Building.



Transverse Sections of Engine and Boiler Room.

In many cases it was necessary to suspend shafting, motors and machinery from the ceilings of this building, and this was done by cast-iron sockets supplied by the Trussed Concrete Steel Company.

The Body Building is separated from the Assembly Building by a court 40 ft. wide. The west end of this court is bridged over to furnish a working floor 50 ft. long by 40 ft. wide. The beams carrying this floor are 18x42 in., reinforced with five 1¼x3¾-in. and five ¾x2-in. bars. The floor construction is the same as in the Body Building. For the finished floor in both buildings 2x3-in. beveled sleepers were laid crosswise of the tile about 16 ft. on centres, the space between being filled with cinder concrete and ⅞ in. maple wearing surface nailed to these sleepers.

Motor Testing Building.—The design of the Motor Testing Building is somewhat similar to that of the Brazing Building, with the addition of two light crane runways. It is connected with the Assembly Building by a covered trolley way.

Garage.—In the Garage Building no interior columns are allowed, as it is necessary to have a large unbroken space in which automobiles can be easily moved around. The entire floor is left clear. Large spans and heavy construction resulted. The roof beams are 16x56 in. at the centre of the building, sloping with the roof to 40 in. at the wall columns. The construction and reinforcement of the building is in the main similar to that of the Brazing Building.

Power Plant.—The power plant supplies the different buildings with electricity for lighting and motor operation, compressed air, filtered city water, Acme gas, live and exhaust steam for heating purposes. The coal pocket is located on the side of the boiler room nearest the railroad tracks and it is 89 ft. 3 in. long, 21 ft. 6 in. wide and 30 ft. 9 in. high. A spur track enters this pocket on a trestle at a height of 13 ft. above the floor and coal is dumped into the pocket by gravity, whence it is delivered to the boiler room stokers by hand. The boilers are equipped with Jones underfeed stokers.

The boiler room is 89 ft. 3 in. long by 45 ft. wide and 25 ft. 3 in. high. It contains at present two batteries of horizontal return tubular boilers, aggregating four units, with space for a fifth, supplied by the Skinner Engine Co., of Erie, Pa. Each boiler is 84 in. in diameter and 18 ft. long, and contains 104 4-in. tubes, with Tupper grates, 84x60-in. and a 6-in. steam outlet. Each boiler discharges into a round breeching carried along the front at the top of the drums, and increasing in diameter from 30 to 54 in. From the breeching the gases are delivered to a Green economizer mounted at the end of the boiler room parallel to the longitudinal axes of the boilers, a by-pass connection being provided from the breeching directly into the chimney. The economizer is supported on columns and beams of reinforced concrete, and contains 352 4-in. tubes 10 ft. 2¼-in. long installed in two sections.

The chimney is reinforced concrete mounted on a reinforced concrete foundation. Its inside diameter is 6 ft. and its height 157 ft. It was built by the Weber Steel Concrete Chimney Co., of Chicago. Owing to the fact that the stack intersected a row of beams in the end of the building, it was necessary to carry cantilever beams to carry the roof up to and around the chimney. This construction did away with the necessity of putting in small columns, and it also keeps the stack clear of the building and the column footings independent of the stack footing.

A special feature of the coal pocket is the provision therein of a reinforced concrete shavings vault 6 ft. wide, 9 ft. long and 22 ft. 6 in. high over all into which shavings are discharged by a 12-in. pipe leading from the Body Building wood working division. The boiler nearest the pump room is served almost exclusively with these shavings.

The pumps for feeding the boilers are mounted in the boiler room at the side of the battery nearest the engine room and consist of two 6x4x6-in. horizontal duplex units. Near the pumps is mounted an Otis feeder water heater. A 3-in. Penberthy injector is also available for boiler feed. The boiler room floor level is 3 ft. 3 in. lower than the engine and pump room floors.

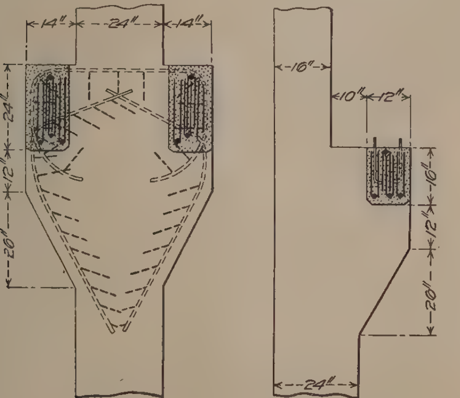
The pump room, between the boiler and engine rooms, is 52 ft. 4 in. long by 18 ft. wide, and it contains at present one 1,000 gal. Knowles underwriter fire pump and two air compressors. One of the latter is a 12x16¼x12-in. Ingersoll-Sergeant machine and the other a 14¼x10-in. compressor of the same make.

The engine room, 79 ft. 3 in. by 52 ft. 4 in., contains space for five units. Two 200-kw. sets, a 125-kw. and a 35-kw. set are now in place, with room for another 200-kw. unit in the future. The engines were all supplied by the Skinner Engine Co., of Erie, and the generators are of Westinghouse make. One of the 200-kw. generators is direct-driven by a 15x20x20-in. engine, tandem compound type; the other 200-kw. generator is direct-connected to a 19x20-in. simple engine, and the 125-kw. generator is run by a 15x16 in. engine. The 35-kw. set has a 10x12 in. engine. The two large machines are 440-volt alterators; and the others are exciters. The switchboard is 6 ft. from the north wall, and it is 20 ft. long. It is separated by a special railing from the rest of the engine room.

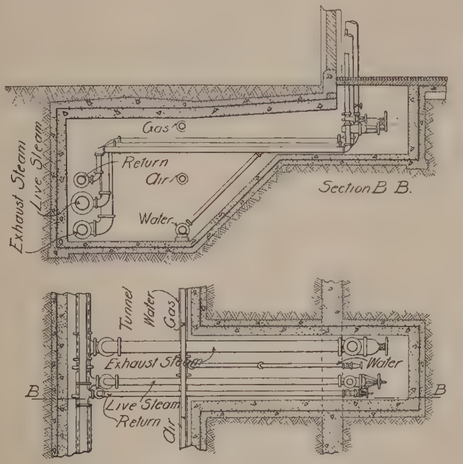
The power house service is supplied to the different buildings through an 8x8 ft. concrete tunnel which leaves the engine room basement near the pump room. There are two live steam mains in the boiler room, each of which increases from 10 to 12 in. in the run past the boilers. At the end nearest the pump room the two mains are cross-connected by a 12-in. pipe which equalizes the steam pressure in the mains and provides a flexible method of securing live steam on either side. One of the mains passes into the engine room, where it delivers steam to the engines by loops dropping down to the cylinders, and the other feeds the fire pump, the two air compressors, and the buildings, via the tunnel. The tunnel line starts as a 10-in. pipe, decreasing as the different building branches are taken from it. This main line is provided with a valve so that all apparatus beyond the fire pump may be cut off.

The fire pump exhaust is a 5-in. line which rises vertically to the roof and terminates in a free exhaust head. The engine exhaust is collected in a basement main which reaches a diameter of 18 in. at the end of the engine room nearest the boilers, and it receives the 7-in. exhaust of the air compressors en route to the feed water heater. The heater is by-passed in the usual manner with free atmospheric exhaust.

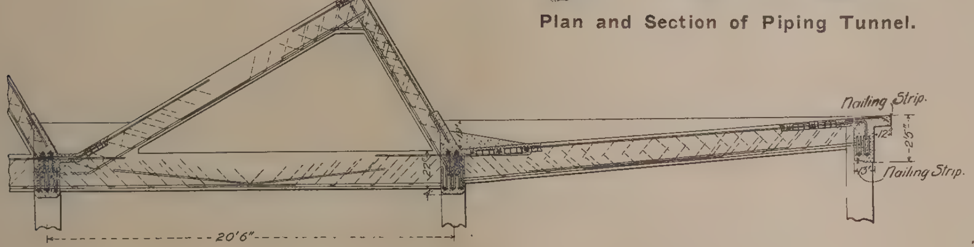
The air inlet pipes on each compressor are 6 and 12 in. in diameter, respectively. These take air from a 12-in. pipe which runs from a concrete box under the pump room floor through the roof to a screen and hood. From the air outlets of the compressors 6 in lines are run to two receivers in the pump room, long radius bends being used on these lines. The two receivers feed the buildings through a 6-in. pipe which runs through the tunnel. A 5 in. air line also is run through the engine room to the Brazing Building, the pipe being supported on the engine room wall behind the live steam main. The fire pump water supply is drawn from the city mains through a 16 in. connection and 12 in. suction pipe, a blank flange for a second 12 in. outlet being provided for a future fire pump of the same size. The fire pump discharges into an 8 in. line, which connects with the hydrant main serving the various parts of the factory.



Crane Brackets on Inside and Wall Columns.



Plan and Section of Piping Tunnel.



Roof Section of Manufacturing Building.

The reinforced concrete tunnel connecting the power house with the various buildings carries live steam, exhaust steam, water, air, gas and return pipes together with electric wires for lighting and power service. All the wiring conduits are carried on the ceiling of this tunnel. Branches are taken off at each building. The top of the tunnel is kept about 2 ft. below the outside grade in order to insure freedom from frost in winter. At the commencement of the tunnel the sizes of these service pipes are: Live steam, 12 in.; exhaust steam, 12 in.; water, 7 in.; air, 6 in.; air to Brazing Building, 5 in.; condensation return, 8 in.; water to Brazing Building, 6 in.; Acme gas, 4 in.; producer gas, 5 in.; water to motor-testing building, 3 in.

Heating.—The method of heating the buildings was devised by the Buffalo Forge Co. In each building a section is partitioned off for a stack of pipes through which exhaust steam is tossed. The air is forced through this heater by an engine-driven fan and discharged through tunnels beneath the floors upward through risers into the rooms. In some cases these tunnels are 6x7 ft. in cross section, and all are built of reinforced concrete. An elaborate system of fire fighting equipment is installed, and the Garage and Body Buildings are provided with an automatic sprinkling equipment because of the value and inflammability of the materials stored in them.

The floor area of the entire plant, including the Administration Building, is approximately 280,000 sq. ft. In the execution of the contract over 1,087 tons of steel and 178,000 sq. ft. of 10 and 8-in. tile were used, together with over 15,000 bbls. of Portland cement. On the completion of the buildings several tests were made. The crane girders in the Assembly Building were tested to twice the working load and the deflection at the centre was less than 1/16 in. At the Body Building a superimposed load of 250 lbs. per square foot was put over a panel, with a deflection of slightly less than 1/32 in. and no permanent deflection was observed.

The buildings were erected in six months by the Concrete Steel & Tile Construction Co., of Detroit. This was about one-third the guaranteed time for either mill construction or steel. The mechanical engineer for the power house was Mr. F. A. Shoemaker, of Buffalo.

The Pacific Building in San Francisco is one of the most important reinforced concrete structures yet undertaken. It is nine stories high, exclusive of a mezzanine floor and basement, and covers an area of 145x195 ft. The reinforced concrete columns are spaced on 16-ft. squares each way. The floors are 4½ in. thick and are reinforced in each direction by 22⅜-in. rods and two sets of four diagonal rods. An interesting structural feature is a spiral staircase of reinforced concrete and another is a cantilever balcony overhanging 6 ft. at the mezzanine floor. The concrete of the wainscoting and baseboards is colored and treated so as to resemble African marble. The facade is faced with terra cotta and glazed tiles in green and brown colors. The ground floor will be used for stores, the basement for a cafe, and each of the eight upper floors is laid out in 64 offices. Dean reversible windows are used throughout, and there are one freight and six passenger elevators.

The Detection of Pollution in Underground Waters.

Extracts from a paper read before the Association of Water Engineers by John C. Thresh, M.D., D.Sc.

The fact of underground water becoming polluted is too often only discovered by a sudden outburst of typhoid fever. Such would probably never be the case were the water submitted to periodical examination. This examination should not be limited to a mere chemical analysis, as from our point of view a bacteriological examination is the more important. If examinations are made systematically, the normal condititon of the water is soon ascertained; and should at any time an abnormal condition be found, its cause can be sought for, and, when detected, it may admit of a remedy. This remedy may possibly prevent outbreaks of disease which sooner or later would have ensued had not the defect been discovered and the remedy applied.

Unfortunately, the cause of the contamination is often very difficult to find, and sometimes one has to admit an utter failure to discover it; but usually this is because the water authority will not go to the necessary expense, or cannot obtain sanction from tenants or landlords to carry out the experiments required. The systematic examinations above referred to often enable the investigator to form some opinion with reference to the character of the polluting matter, and its proximity to the source of the water. For example, a certain well water yielding about a million gallons per day gives unexceptional chemical and bacteriological results save on rare occasions when there is a very heavy rainfall. Within twenty-four hours of a downpour, the number of bacteria present in the water increases enormously. Some of these are of an objectionable type; but they disappear again almost as quickly as they appeared. Chemically the water undergoes a scarcely appreciable change. Here it is obvious that the microbes do not come from any great distance—in fact, their source cannot be far from the well. Their nature indicates that they are derived from manured soil; and an examination of the surrounding area leaves little doubt as to their sources. In another instance certain objectionable bacteria appeared in a spring water supplying a small town; but their appearance was many days after an appreciable rainfall. An examination of the collecting area showed that there were large gravel pits about 200 yards away, and that recently some house refuse had been tipped therein. Experiments were carried out which established the connection between this gravel pit and the spring; showing that it would be exceedingly dangerous to allow house refuse to be tipped therein.

Before making experiments with chemicals, a careful survey of the whole position must be made. The geology of the district must be studied, the depth and section of the well and the length and direction of any adits must be known, as the records of the systematic analysis must be considered and compared with the rainfall and with the height of the water in the nearest ponds or streams. Some information must be sought with reference to the direction of flow of the subterranean water, and as to the cone of depression caused by pumping. The position of the outcrop of the water-bearing stratum may also require to be known, so that it may be examined, if not too far away to be possible source of danger. If evidence can be obtained of the presence of fissures, and of their extent and direction, it may prove of the utmost value in the investigation. All the possible sources of pollution must then be sought out and considered in connection with the knowledge so ascertained. This will enable the investigator to determine which is most likely to be the cause of the trouble, and therefore the one which should first receive attention. If such experiments as will be described shortly fail to show any connection between this possible source of pollution and the spring or well, attention must be directed to the next most probable source, and so on, until something definite has been determined.

It is not always the well with apparently the best surroundings that yields water of most uniform quality, nor the well with doubtful surroundings which yields water of most varying quality. Take, as an example, the well of the Windsor Corporation Waterworks. It is sunk in the chalk on an island in the Thames—and the character of the Thames water is too well known to need description. It would seem almost certain that this well would be affected by the river, and that in times of flood the water would show unmistakable signs of being so affected. Such, however, is not the case. Careful chemical analysis show that there is a decided difference in the same saline constituents of these waters; and the bacteriological examination fails to give any indications of great rises in level of the Thames water. As another example of the opposite character, one may mention a very deep well in the new red sandstone—one of a series of four—which often shows unmistakable signs of contamination with surface water, yet the surroundings are almost ideal; and a probable source from which any polluting matter can be derived has not yet been found.

To ascertain whether a given source of pollution can affect a given well, it is usual to introduce some chemical at the point of suspicion, and then to examine the water at frequent intervals to ascertain whether the chemical selected can be detected in it. For this purpose common salt (sodium chloride), a lithium salt, or a dye named fluorescein have been employed; and recently the author has used ammonium salts, since, in certain cases, it possesses advantages over the others. Sodium chloride is used chiefly because it is very cheap, easily obtainable, quite innocuous, and easily detected and estimated in the water. As all waters contain chlorides, the normal chloride must be first ascertained, then any subsequent increase during the experiment may be attributed to the salt used. Slight variations are often observed in water from the same well. Consequently enough salt must be added to produce a more marked effect than any recorded in the normal water. The quantity must be at least equal to one grain of salt per gallon (=0.6 grains Cl.). Should it prove necessary to add this amount to a large quantity of water, the weight of salt used must be considerable. For example, it may be necessary to add sufficient salt to materially increase the chlorine content of a million gallons of water. To do this would require 1,000,000 grains, or 143lb. of salt—an amount which can easily be handled and readily dissolved and passed into the soil. If, however, it is estimated that at least 100,000,000 gallons of water will have to be affected, then six to seven tons of salt must be used—an unwieldy quantity, difficult to deal with. Where anything like this volume of water has to be considered, a substitute for salt would now be used.

One of the best examples of the use of salt is recorded in connection with an outbreak of typhoid fever at New Herrington, Durham, in 1889. The well, when inspected, was found to receive water from various fissures; and one at a depth of 45 ft. from the surface came under suspicion, since the water therefrom contained more chlorides than the water entering elsewhere. From a study of the dip of the strata and direction of the fissures, it was surmised that there might be a connection with a farmyard about three-quarters of a mile away, since the sewage from this farm disappeared down a fissure and was no more seen. Two experiments were made; two tons of salt being used in the first and five tons in the second. This was washed into the fissure with an enormous volume of water. On the following day the chlorine in the water in the fissure increased from four to six grains per gallon—its ordinary limits of variation—to 15 grains per gallon; and in six days it reached a maximum of 24 grains. A few days later it fell to the normal amount.

Another example quite as conclusive, but in which a much smaller quantity of salt was used, may also be quoted. The *bacillus coli* was frequently found in a public supply derived from a spring in the mountain limestone. The chemical analysis of the water gave uniformly good results, and the chlorine was constant at 1.6 grains per gallon. This low chlorine figure, and its constancy, did not indicate direct pollution with sewage; and a careful survey of the neighborhood led to the suspicion that the polluting matter entered at a fissure in some marshy ground about half a mile away. The soil round this fissure swarmed with the *bacillus coli* and similar organisms, probably derived from a farmyard a little distance above. A little fluorescein was placed in the water which could be seen in this fissure; and it disappeared so quickly that it was obvious that there was a rapid flow of water. It was considered too risky to put a large quantity of coloring matter in. Consequently, at 10.30 o'clock on a Wednesday morning, half a ton of salt was shovelled in, and samples of water were collected at frequent intervals from the spring. The results were as follows:—

GRAINS OF CHLORINE PER IMPERIAL GALLON IN THE SPRING WATER.

	Wednesday.	Thursday.	Friday.
9.00 a.m.	—	—	1.6
9.30 "	—	1.6	—
10.30 "	1.6	1.6	—
11.30 "	1.6	1.6	—
12.30 p.m.	1.6	—	1.6
1.30 "	1.6	1.6	—
2.30 "	1.6	—	—
3.30 "	1.6	2.1	1.6
4.30 "	2.0	—	—
5.30 "	2.0	2.1	1.6

Pumping ceased.

In this case it was obvious that the water from this fissue only entered when the level of the water in the reservoir over the spring was depressed by pumping; and on comparing the levels it was found that such must be the case, as when the reservoir was full the water level was practically the same as the level of the water in the fissure.

A salt of lithium has frequently been used instead of salt. Exceedingly minute quantities of this can be detected by means of the spectroscope. A crude lithium sulphate, which answers every purpose, can now be purchased at 4s. per lb. About one part of this salt in 1,000,000 of water may be detected—1 grain in 14 gallons—and inasmuch as lithium is not a normal constituent of potable waters, its detection after the use of salt is positive proof of direct connection between the point where the lithium has been placed and the source of the water. Unfortunately, the detection of such minute traces in a considerable amount of deposit left by the evaporation of the water is very tedious and troublesome; and to use any quantity of the substance very expensive. For these reasons lithium salts are now rarely employed.

The author has recently used ammonium chloride—sal ammoniac—in several investigations, with marked success. It is very cheap, free from color, perfectly harmless, and the ammonia, even in great dilution, admits of easy detection and estimation. When 7 lb., costing about 3s. 6d., is dissolved in a million gallons of water, the ammonia can readily be detected. The amount of ammonia present in all good subsoil waters is too trifling to interfere. But certain very deep wells, yield waters and many polluted waters contain very varying quantities of an ammonia salt might not lead to definite conclusions. It must also be remembered that the salt must be put directly into the subsoil water or fissure, as if spread on fertile ground a portion of it might be nitrified by the nitrifying organisms of the soil. Probably, however, in any case, the amount nitrified would only be an infinitesimal portion of the salt employed. On the whole, it may be regarded as much more convenient for use than either common salt or salts of lithium. In one of the experiments already referred to, where objectionable bacteria in a spring water were traced to the deposition of house refuse in a gravel pit, ammonium chloride was the salt used. The records of the experiments are as under:—

December 12th.—Four pounds of ammonia chloride placed in a hole in the gravel pit and water poured in until the salt had disappeared. Samples of water collected and examined daily until January 15th. On December 26th the water contained a distinct trace of ammonia; on no other day during December was ammonia discovered.

On January 14th the ammonia again suddenly appeared in marked quantity; but next day no trace could be discovered. The rainfall was as under:—

Dec. 12	0.02	inch
13	0.36	"
14	0.08	"
15	0.19	"
16	0.30	"
17 to 23	0.00	"
24	0.07	"
25	0.31	(3½ in. snow)
26	0.06	as snow
27	0.15	"
28	0.13	"
29	0.00	
30	0.22	snow and rain
Jan. 1	0.35	snow melted.
2	0.13	
3 to 5	0.00	
6	0.01	
7 to 9	0.00	
10	0.20	
11 to 18	0.00	

The heavy rains from December 13th to the 16th apparently affected the spring water on the 26th; and the rain and melting snow on January 1st and 2nd also carried the ammonia from the gravel pit to the spring, affecting it on the 14th. There is no doubt that water from the gravel pit reached the spring in from ten to fourteen days, after a heavy rainfall. Ammonium sulphate would probably answer equally as well as the chloride, and as it was manufactured on a large scale for use as an artificial manure it is much cheaper. It may, however, contain large traces of arsenic, which renders it necessary to examine the sample before deciding to use it.

Another substance of an entirely different character, which is of special importance in such investigations as the above, is a coloring matter called fluorescein. Many of the aniline dyes possess enormous colorific power; but most of them, when in very dilute solution, are colorised by filtration through soil, and others are too expensive or are objectionable in other respects. Fluorescein appears to be unaffected by passage through chalk, sand, surface soil, &c., and when dissolved in water by aid of an equal weight of caustic soda it can be easily detected by its fluorescence when the dilution is 1 in 100 millions. Under very favorable conditions 1 in 200 millions may be detected. In other words, 1 lb. of fluorescein will distinctly color 10 million gallons of water. As the demand for this substance has increased, the price has gone down, until it can now be purchased at 7s. 6d. per lb. in quantities of 10 lb. and upwards. The relative cost of these various substances used in sufficient quantity to affect one million gallons of water would be fluorescein; 9d.; common salt 2s.; ammonium chloride, 3s. 6d.; and lithium sulphate, 40s. Fluorescein is, therefore, much the cheapest; it is the easiest to apply, and far the easiest to detect. There is only one possible objection to it, and that is that, if used incautiously, it may so colour the whole of a water supply as to cause alarm on the part of the consumers. For this reason it is in most cases preferable to use salt or ammonia chloride in the first instance; and if, when used in moderate quantities, these give no definite results, to employ fluorescein. This dye has been largely used for tinting underground streams to trace their course, and to a certain extent for determining the direction and rate of flow of subsoil water, and one case is recorded where it unexpectedly made its appearance in a public water supply, and caused considerable astonishment and some alarm. More recently it has been applied for the special purposes dealt with in this paper, and some recent experiments carried out on a somewhat large scale near Cambridge may be cited as examples.

In 1905 a series of cases of typhoid fever occurred at the County Asylum near Cambridge, and the Local Government Board instructed Dr. Monckton Copeman to investigate it, and more especially to report with reference to the risk of pollution of underground water supplies by the sewage of the asylum. A detailed description of the geology of the district is given in Dr. Copeman's report. The asylum sewage was disposed of by a crude system of broad irrigation on land, which consists of a thin layer of loamy soil covering the chalk. The well supplying the asylum is about 60 ft. deep, and some 1200 ft. to the west of that portion of the irrigation area selected for experiment, and about 2500 ft. east from a well, 70 ft. deep, which furnishes the chief supply to the city of Cambridge. A hole was dug to the chalk on the irrigation area and 0.5 kilos. of fluorescein dissolved by aid of caustic soda was washed into the chalk and samples of water from pits and wells around afterwards collected for examination. The results not being conclusive a further experiment was made, using 5 lb. of fluorescein. The experiment was started at 11 a. m. on October 18th, and at 3 p. m. the color appeared in a pit 200 ft. N. N. E.; at 9 a. m. on the 20th it was found in a pit 700 ft. E. N. E.; at 4.30 p. m. on the 21st it was seen in a pit between the sewage plot and the pit in which it was observed on the previous day; on October 22nd it was found in the water of the asylum well; and on October 27th it was found in the water of the Fulbourne well. It had therefore taken 103 hours to travel about 1200 ft. westward, and about nine days to travel 2500 ft. to the eastward. The wide diffusion is an interesting point, as the wells both to the east and west were affected. At no time previously had these waters come under suspicion, and neither bacteriological nor chemical analyses apparently had ever indicated contamination. Dr. Copeman therefore adds: "It does not, of course, necessarily follow, because the fluorescein should have proved capable of detection at various points, inclusive of the asylum well, at so great a distance in different directions from the point at which it was introduced, that bacteria, harmful or otherwise, would be equally capable of transmission for so considerable a distance, but, nevertheless, the results of these experiments are decidedly instructive and important."

The Asylum Committee were advised to make some arrangement for dealing with their sewage which should remove all risk of the effluent contaminating either of these sources of water, and the author was requested to report upon the best method of securing this desirable result. A study of the geology of the district had led him to infer that, beyond a certain line, the underground water would be travelling in a direction away from these wells; and to prove this a hole was bored on the site, and 2 lb. of fluorescein dissolved and suitably diluted, was poured into the bore. It quickly disappeard; but although all the pits, walls, springs, &c., around were watched, no trace of the coloring matter was ever again seen. A further experiment on a larger scale was therefore decided upon, and carried out in the following manner:—Two bore-holes, 30 ft. deep, were made at opposite sides of the field selected. They were 110 yards apart, and both yielded water freely. A trench was cut from a point six yards north of the south bore to a point six yards south of the north bore. This trench was 96 yards long, 1 ft. wide, and 6 in. deep. Water was pumped from the south bore at the rate of 25,000 gallons per day; but it filtered through the trench so rapidly that a pump had to be placed in the north bore. When the second pump was started the whole of the trench could be flooded, and also a shorter trench cut at right angles and communicating with it. Pumping was kept up for three days to thoroughly saturate the ground before the fluorescein experiment was commenced on March 8th. A tub was mounted at each end of the long trench; and in each was placed 1 lb. of the dye. While pumping was continued the solution was allowed to dribble into the water as it entered the trench. The time taken in running in the solution was, on an average, four hours. Four pounds were put in on the 8th, 4 lbs. on the 9th, 2 lb. on the 10th, and on the 12th 1 lb. was run directly into the north bore-hole.

The amount of dye used would have distinctly coloured about 150 million gallons of water. Watch was kept at seventeen different points. At no time did any colour appear in the south bore-hole; but in the north bore-hole the water was tinted seven hours after the commencement of the experiment. No trace of colour appeared elsewhere until nine days later, when the water in a chalk pit 300 yards N. N. W.; on March 31st, the color observed in a well water 1200 yards further N. N. W.; and on April 7th it was detected in the marsh water near the river Cam, about 3000 yards away, still in the same direction. At no other points has any trace of color been detected. The second experiment, therefore, not only confirmed the first in so far as it showed that water from this locality did not travel towards either of the wells, but it also proved that the colored water travelled in a definite direction, which, fortunately is quite away from the sources of supply. The depth of color observed has never been greater than that produced by 1 part of the dye in 130 million parts of water, save at the north bore-hole, where it was much more deeply tinted.

To do away with any doubt as to whether bacteria can be conveyed from any given point to a deep source of water, it has been suggested that certain easily recognized bacteria should be introduced into the soil at the point where pollution is suspected to arise, and to examine the water repeatedly for the special bacteria. Experiments of this kind have been recorded, and it has been shown that bacteria can be washed by very heavy rain through a few feet of soil into collecting trenches beneath, but they have never been traced any considerable distance. The author's experience with this test, using the bacillus *prodigiosus*, has not led him to regard it with any favor, nor would it justify him in recommending it, though one can conceive cases in which such a test would afford information of some value. Some time ago, the author commenced a series of experiments in a brick channel about 36 ft. long, 1 ft. wide and 3 ft. deep. A little shingle was placed along the bottom, and the trench was filled up with fine sharp sand, such as is used by builders. At intervals of a yard glass tubes 2 in. in diameter were inserted 2 ft. into the sand, and water was run in until the water level was about 1 ft. from the surface. Water was then allowed to flow away slowly from the bottom of the trench at the opposite end to that at which the water was being introduced, and a condition of equilibrium maintained. An emulsion of the *bacillus prodigiosus* was then placed in the tube nearest the water inlet, and samples of water were collected from the other tubes and also from the outlet. In every experiment the bacillus was detected in the outlet water in a few hours, but it was never discovered in the water in the tubes. Apparently the microbes were first carried downwards into the shingly layer and then carried forward to the outlet. The results merely showed that polluting matter on a collecting area may pass downwards, get into a stratum of greater porosity, and then travel a considerable distance.

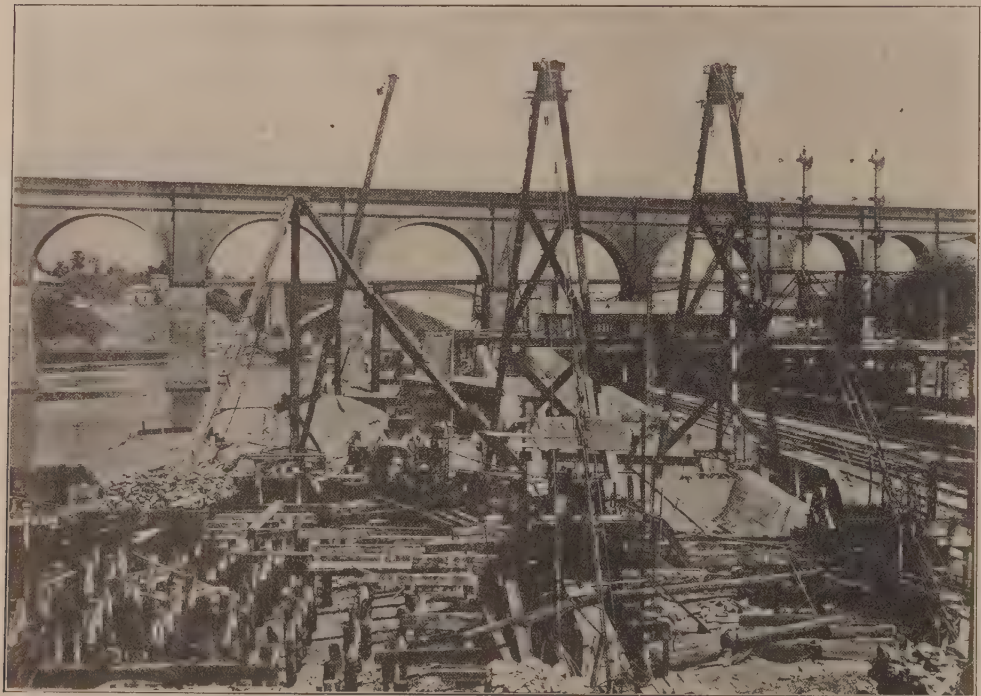
Afterwards the same organism was used in connection with the gravel pit referred to in the ammonium-chloride experiment, but the bacillus never showed itself in the spring water. As there is undoubtedly a connection between this gravel pit and the spring, as was proved by the ammonium-chloride test, possibly one might conclude that it was not of such a character as to permit of objectionable bacteria going into the spring water.

The difficulty and trouble in carrying out such a test are very great, and the instances in which it is desirable are very few. Possibly in every case a comparatively simple experiment with fluorescein, together with a series of ordinary bacteriological examinations, would give more valuable and reliable information.

Another Polar Railway is contemplated by a leading Russian engineer and contractor named Knorre, who has recently received the concession for the Polar-Ural R. R. He has been over the entire route and says that it is perfectly practicable, with an easy grade over the Ural Mountains. This road is intended to help the development of agricultural western Siberia. It will be the outlet and inlet for the splendid water freight routes of the Yenesei and Ob rivers and of the Irtish, the great tributary of the Ob. It will more than double their importance, because it will do away with the difficult, dangerous and uncertain navigation of that part of the Arctic Ocean called the Kara Sea. The railroad that will now be built will start from Obdorsk on the Ob River at the Polar Circle and extend northwest across the tundra to Bolvansk Bay, the southern part of Pechora Bay, about 266 miles. As compared with the Kara Sea route the railroad will shorten the distance between the Siberian rivers and the ports of western Europe by about 1,000 miles, as by the route now used vessels have to travel far north to circumvent the Jalmal Peninsula. Pechora Bay is open for commerce more than four months in the year, and the navigation season on the great rivers of western Siberia is still longer, while in the great grain region of the southwest on the upper Ob and the Irtish it is six and a half months. All the large trade centres of the southwest, as Tobolsk, Pavlodar, Semipalatinsk, Tomsk and Barnaul are on the Ob and Irtish highways leading direct to the railroad, whence the journey will be safe and easy to all the leading ports of northwest Europe.

Elimination of Grade Crossings in New York Central Electric Zone.

The frequent train service inaugurated in connection with the electrical operation of the New York Central & Hudson River R. R. has made it necessary for the safety of the public and the efficient movement of the traffic that all grade street crossings within the Electrical Zone in New York City be abolished. This is being accomplished at some points by means of overhead bridges and at others by carrying the street under the elevated track. At the High Bridge and Morris Heights stations the former plan has been adopted. At these stations the four tracks of the Hudson division and the two tracks of the Putnam division occupy a strip on the east side of the Harlem River parallel to the river's general course and 150 to 300 ft. from the water's edge. The tracks are a little higher than the wharves along the water front. The station buildings at High Bridge and Morris Heights have their main street entrances on the second floor, which is at the same elevation as a steel girder bridge 10 ft. wide which in each case extends along the front of the station across the railroad tracks. This bridge connects at its west end with an incline leading down to the area along the water front and at its east end with one or the other of the streets mentioned in the title. In construction and design the structures over the railroad tracks afford no features of special interest. Their east approaches are formed by earth fill between dry rubble masonry walls. The construction of the west approach in each case, however, involves heavy concrete work which has been handled by efficient methods.



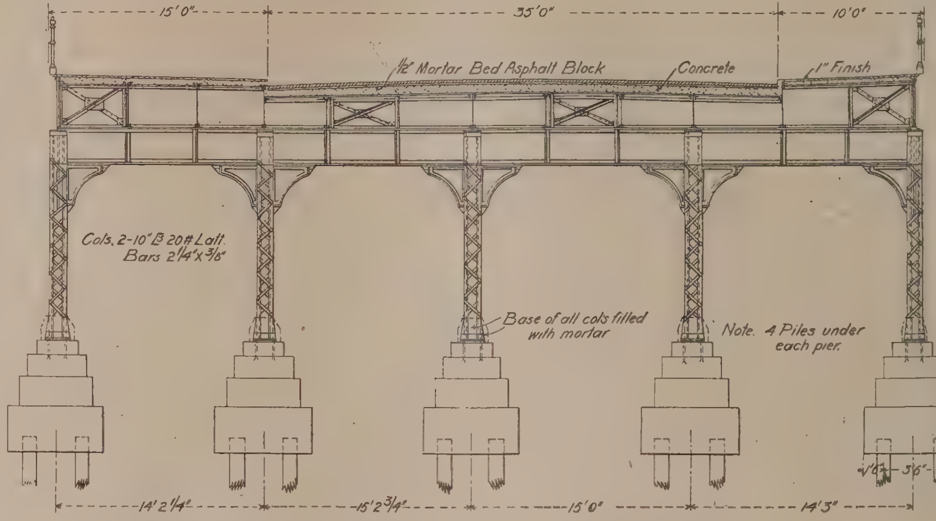
Approach to Bridge over Railroad Tracks at High Bridge Station.

At the Depot Pl. or High Bridge station the approach to the west end of the bridge over the tracks consist of a straight ramp about 525 ft. long which extends southward parallel to the railroad track and the bulkhead line close to the former. This ramp, which is on a 4.3 per cent. grade, consists of an earth fill between plain concrete walls having the maximum and minimum sections shown in an accompanying illustration. The clear width between the coping courses is 23 ft. 2¾ in. Of this, 5 ft. along the river side is devoted to a bluestone flag sidewalk and the remaining width is occupied by a granite block pavement on a sand foundation with a single gutter along the sidewalk curb. The wall concrete is a 1:3:6 mixture of Lehigh Portland Cement, sand and gravel and the coping concrete is a 1:2:4 mixture of the same materials. Tongue-and-groove 2-in. pine plank forms in 2½x16-ft. units are used and a 1-in. finishing coat of 1:2 cement mortar is applied as the wall concrete is laid by means of thin sheet-steel finishing plates.

The wall footings are about 6½ ft. below mean high water and rest on piles, 20 to 55 ft. long, whose tops are embedded 1½ ft. in the footing concrete. These piles are placed in three longitudinal rows where the over-all height of the wall exceeds about 24 ft. and in two rows where the wall is lower. The spacing of the piles in each line varies from 3 to 4½ ft. according to the weight supported.

The two walls have been carried forward from the lower toward the upper end of the ramp in 59-ft. sections, the work alternating from one wall to the other. Expansion joints are formed with one thickness of heavy tar paper placed as shown in accompanying sketches. Wooden sheet piling is used and two Cameron steam pumps, sizes 9 and 11 have been employed to keep the water down while the footing concrete was placed.

Near the south end of the ramp the roadway is carried over an old abandoned canal, the bottom of which is above low tide, with a plate-girder and reinforced concrete bridge. There are three 42½-in.x36-ft. girders placed 13 ft. ⅝ in. on centers carrying 15-in. 42-lb. I-beam floor beams on about 6-ft. centers. The 13x6-ft. panels thus formed are covered with a continuous 7-in. slab of concrete reinforced in a direction parallel to the course of the canal with ¾-in. round steel rods on 12-in. centers and in a direction parallel to the center line of the ramp with the same size rods on 6-in. centers. This canal formerly served an entrance to a neighboring coal yard, but it was abandoned long ago.


15′0″
35′0″
10′0″
1½″ Mortar Bed Asphalt Block
Concrete
1″ Finish
Cols. 2-10″ [20# Latt. Bars 2¼″x⅜″
Base of all cols filled with mortar
Note. 4 Piles under each pier.
1′6″
3′6″
1′6″
14′2¼″
15′2¾″
15′0″
14′3″

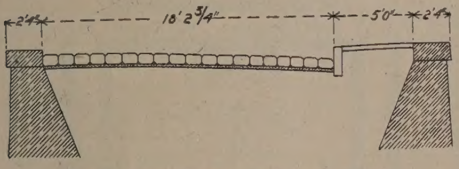
Section of Steelwork of Morris Heights Approach.

Sand and gravel is delivered alongside the work on lighters holding about 600 cu. yd. each. Each lighter is loaded with both materials, the proportions being the same as required for the concrete. The boats are unloaded by shoveling the material into 1-yd. buckets which are delivered to storage piles near the mixer on shore or to the mixer itself by a stiff-leg derrick placed at the water's edge on the north side of the canal and operated by a Lidgerwood hoist. The 1-yd. Smith mixer is placed near the derrick on a slightly elevated platform and delivers to 1-yd. buckets which are conveyed to the proper point along either wall by two cable-ways, one over each wall. One of these cableway outfits was made by the Lidgerwood Mfg. Co., New York City, and the other by W. A. Crook & Bros., Newark, N. J. The cableway engines are mounted one on the extreme south end of each wall and the guyed A-frames forming the towers are placed on the south abutment of the canal bridge and beyond the north line of the bridge over the railroad tracks, as shown in an illustration. Steam is supplied to the various engines and pumps by a 60-h.-p. Erie boiler and a 40-h.-p. locomotive boiler formerly used on the New York elevated railroad. These boilers are in a shed about 100 ft. north of the old canal and close to the west wall of the ramp. The cableway conveyors are being used to deliver the filling material which is brought alongside the work on scows and placed between the walls before the coping courses are built.

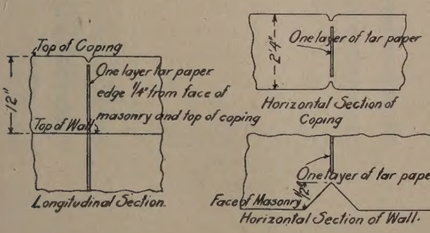
For the convenience of the users of the water front at the High Bridge station, pending the completion of the permanent improvements, a timber incline has been built just outside the west line of the west wall connecting at its upper end with the bridge across the track.

At the 177th St. or Morris Heights station the bridge over the tracks will be extended westward about 141 ft. by a similarly designed elevated steel structure 60 ft. wide, carried by five longitudinal lines of latticed columns spaced 34 ft. 8 in. center to center in each line. The longitudinal floor girders are spaced in general on about 5-ft. centers, thus dividing the floor into long panels about 5 ft. wide. The 9-in. reinforced concrete floor carrying the 35-ft. roadway, rests on the longitudinal girders and is reinforced with ½-in. round rods, those parallel to the girders being on 12-in. centers and those perpendicular to them being on 6-in. centers. A 15-ft. cement sidewalk extends along the north side of the bridge roadway and a similar walk 10 ft. wide is on the south side. These sidewalks and the roadway slope downward on a 4 per cent. grade to the extreme west end of the steel structure where they meet a concrete and earth fill incline U-shaped in plan, as shown in accompanying illustrations.

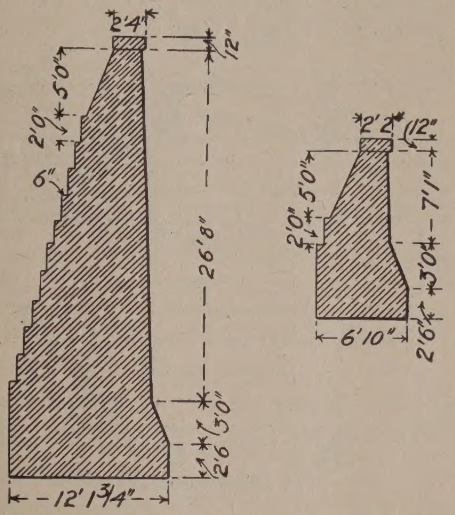
In general, the concrete walls of this plant have the same sectional form as those at High Bridge and are built of the same materials in the same proportions. The high transverse wall at the east end of the earth fill, however, has a much heavier section than the other walls since it serves as an abutment for the west end of the steel structure. The pile supporting these walls are 20 to 53 ft. long.



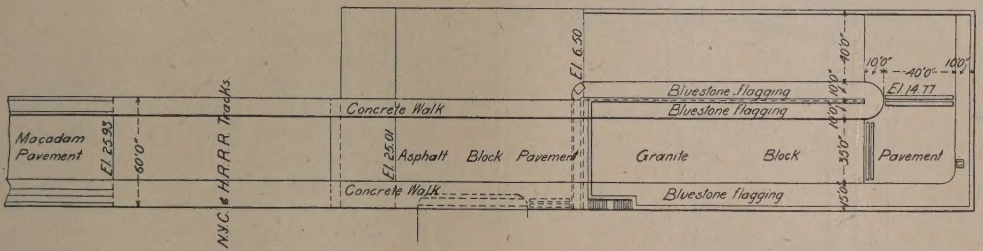
Section of Ramp at Depot Place.


Top of Coping
One layer tar paper edge ¼" from face of masonry and top of coping
12"
Top of Wall
Longitudinal Section.
2'4"
One layer of tar paper
Horizontal Section of Coping
One layer of tar paper
Face of Masonry
Horizontal Section of Wall.

Expansion Joint.



Maximum and Minimum Wall Sections at Depot Place.



Plan of Approach at Morris Heights Station.

Sand and gravel is delivered at Morris Heights in lighters, as at High Bridge. During the early stages of the work these were unloaded with 1-yd. buckets handled by a small stiff-leg manually-operated derrick. The abutment and the center and north walls were constructed first. While this work on these was in progress, the mixer, a 1-yd. Smith machine, was placed on a slightly elevated platform near the middle point of the center wall on its south side. Sand and gravel was hauled from the lighters to storage piles near the mixer in dump wagons and the mixer was served from the storage pile by wheelbarrows. The mixer delivered to 1-yd. buckets which were handled by a stiff-leg derrick with an 85-ft. boom, placed between the center and north walls about 80 ft. west of the abutment wall and operated by a Lidgerwood hoist. Later during the construction of the west and south walls the mixer was placed in the corner formed by the south and west walls on an elevated platform, the small derrick was replaced by one with a 70-ft. boom operated by a Lidgerwood hoist, and the large derrick mentioned before was mounted at the west end of the center wall from which point it could reach the mixer and the forms for the west and south wall.

In handling the water encountered at Morris Heights, two Cameron steam pumps of the same sizes as those at High Bridge were used. Steam was supplied to the pumps and hoists by a 60-h.-p. Olney & Warren boiler placed near the east end of the south wall.

The structures immediately over the railroad tracks were built by the New York Central & Hudson River R. R., and the approaches are being constructed by the City of New York. Mr. Josiah A. Briggs, chief engineer of the Borough of the Bronx, New York City, exercises general supervision over the work which was planned and is being executed under the immediate supervision of Mr. S. C. Thompson, principal assistant engineer of highways. The approaches at High Bridge and Morris Heights are being constructed under one contract, Mr. J. C. Rogers being the contractor. The construction work which is now in charge of Mr. Chas. Gartensteig, assistant engineer, was begun by Mr. R. H. Gillespie, assistant engineer, who resigned last May to take up other work. The American Bridge Co. will fabricate and erect the steel structure at Morris Heights.

Railway Statistics from advance sheets of "Poor's Manual" show that the average receipts per passenger-mile in 1906 were 2.011 cents, as against 2.028 cents in 1905. The average revenue per ton-mile in 1906 was 0.766 cent, as against 0.784 cent in 1905. At the close of the year there were 222,635 miles of railway.

Sewage Disposal Results at Berlin, Ont.

A sewage disposal plant, comprising two septic tanks, two storage tanks, a pumping station and 14 acres of intermittent sand filters in 16 beds was placed in operation at Berlin, Ont., in 1905. Since then samples of sewage from various parts of the plant have analyzed by the chemist and bacteriologist of the provincial board of health of Ontario from time to time to determine the efficiency of the plant. The average results determined by these tests are given in the accompanying table. From these results it may be seen that the average removal of albuminoid ammonia from the raw sewage by the septic tanks and filters was 91.8 per cent., and the average removal of albuminoid ammonia from the effluent of the septic tanks was 84.14 per cent. On no occasion was the effluent from the filters putrescible.

Table 1—Average Results of Tests to Determine Efficiency of Sewage Disposal Plant at Berlin, Ont.

Description.	No. of Specimens Examined.	Parts per 100,000 — Free Ammonia.	Parts per 100,000 — Albuminoid Ammonia.	Parts per 100,000 — Chlorine.	Percentage Removal by Septic Tanks and Beds of Albuminoid Ammonia Over Raw Sewage.	Percentage Removal by Each Bed of Albuminoid Ammonia from Septic Tank Effluent.
Raw sewage	19	2.935	1.406	29.13	....	....
Septic tank effluent	20	2.450	0.723	27.08	48.5	....
Beds 1 and 2	13	0.594	0.172	20.23	87.7	76.2
Beds 3 and 4	10	0.982	0.169	21.08	87.9	76.6
Beds 5 and 6	11	0.798	0.133	20.78	90.5	81.6
Beds 8 and 11	7	0.5735	0.1159	20.40	91.8	84.0
Beds 9 and 10	9	0.305	0.093	14.83	93.9	87.1
Bed No. 12	8	0.142	0.080	21.05	94.3	88.9
Bed No. 13	8	0.342	0.089	22.82	93.6	87.6
Bed No. 14	8	0.291	0.118	18.37	91.6	83.6
Bed No. 15	3	0.3413	0.0437	18.43	96.9	94.0
Bed No. 16	10	1.176	0.131	24.44	90.6	81.8

This sewage plant and the conditions governing its design and operation were fully described in The Engineering Record for Dec. 23, 1905. Briefly, the combined capacity of the septic tanks and storage tanks is 500,000 gal., which is approximately the average daily sewage flow. Of this flow nearly 200,000 gal. is trade wastes from a brewery, a woolen factory, a gas works and four tanneries. Formerly these wastes rendered the sewage particularly difficult to treat, but a series of experiments conducted prior to the construction of the disposal plant demonstrated that they could be made much less harmless by simple treatment of different kinds before being turned into the sewers. Provisions have been made for the preliminary treatment of these wastes so that their influence on the activities of the septic tanks and filter beds is much reduced.

The disposal plant was designed by Mr. Wm. Mahlon Davis, consulting engineer, of Berlin, Ont., who has supplied the data concerning the results obtained by it.

A Turbine Test of a 1,000-kw. Allis-Chalmers unit was recently made at the power-house of the Kokomo, Marion & Western Traction Co. by Mr. Paul Diserens of Purdue University and representatives of the owners and builders. The turbine was designed for 1,000 kw. at 1,800 r.p.m., using dry saturated steam at 140 lb. at the throttle and 28-in. vacuum at 30-in. barometer. The auxiliaries include a motor-driven exciter, a steam-driven exciter, two small circulating pumps, and a standard Allis-Chalmers turbo-jet condensing apparatus. The average load during the test was 553.3 kw. and the run was 4 hours. The steam pressure at the turbine throttle was 136.4 lb. and at the turbine inlet 61.9 lb. The vacuum was 26.59 in. with the barometer at 28.98 in., equivalent to a vacuum of 27.66 in. with a 30-in. barometer. The turbine ran at 1,800 r.p.m. The water used was 55,662 lb., the drip 450.6 lb. and the boiler leakage 5,344.6 lb. The moisture in the steam was 2.82 per cent. by calorimeter. Dry steam supplied to the turbine per hour 12,115 lb., and the actual consumption 21.9 lb. per kilowatt-hour, the guarantee at half load being 24 lb. with a 28-in. vacuum.

A Method of Tunneling High Railroad Embankments for Culverts.

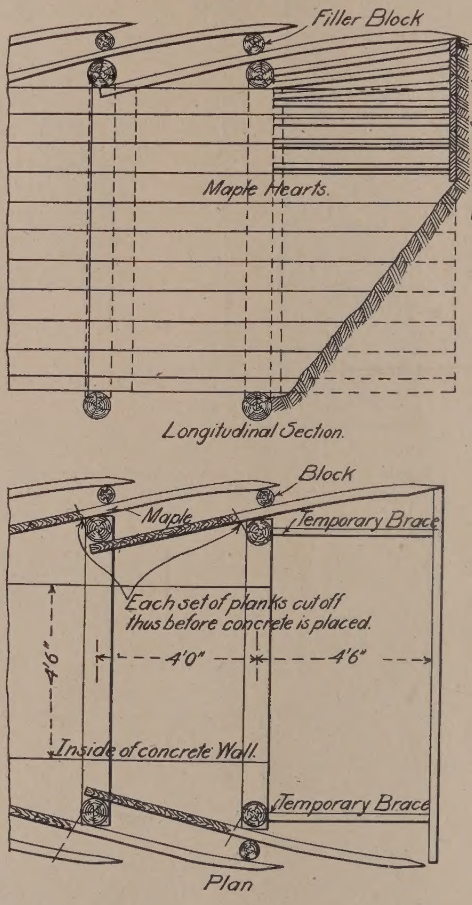
A wooden-box culvert and two cast-iron pipes which have failed under high embankments of sand on the Lake Superior & Ishpening Ry. are being replaced by reinforced-concrete culverts built in tunnels driven through the embankments. A flat-top reinforced-concrete culvert, 190 ft. long, 4.5 ft. wide inside, 4 ft. high at the sides and with a curved invert, giving it a clear inside height of 4.5 ft. at the longitudinal center line, is being built to take the place of a 60-in. cast-iron pipe which failed under an embankment 65 ft. high. A concrete culvert, 284 ft. long and 3x3 ft. in cross section inside, replaces a 36-in. cast-iron pipe under a 95-ft. fill, and one 150 ft. long and 4x4 ft. in the clear in cross-section will supersede the wooden-box culvert which is under a sand fill, 50 ft. in height.

One of the embankments through which these culverts are being constructed was made eleven years ago, when the road was built and the other two, seven years ago, at the time a cut-off from the original line was built. Their height and the material in them precluded any possibility of constructing the culverts in open cut, so a tunnel had to be built through each of the embankments. The comparatively small cross-section required in these tunnels, the character of the sand through which they were to be driven and the necessity of avoiding settlement that would interfere with the heavy traffic on the track carried by the embankment necessitated the adoption of a method of tunneling which would insure both safety and economy.

The tunnel for the largest culvert is 6x7.5 ft. in the clear inside the timber lining, and those for the two smaller culverts are of proportionate size. The method of excavating and timbering the three tunnels is practically the same, so one description and the accompanying illustration will suffice for all. The timbering consists of framed bents of Norway pine or tamarack logs, at least 8 in. in diameter, and 3-in. hard-maple planks for sheeting on the sides and top. The bents are spaced 4 ft. apart on centers, each bent having a bottom sill, two vertical posts and a cross brace connecting these posts at the top, these pieces all being in 8-ft. lengths. The sheeting is driven as closely together as possible and is arranged so a double row of it with a space between the rows, is provided on both sides and the top at all places.

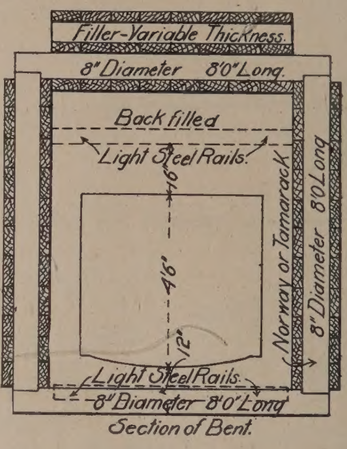
After a start has been made in the side of the embankment by setting two bents in their regular positions and driving the sheeting, the excavation and timbering is carried forward through the balance of the tunnel by the following method: The face of the excavation is closely sheeted with horizontal planks placed against the front side of the last bent erected in order to hold back the fine sand; these planks extend from the bottom of the tunnel to the sheeting at the top so as to prevent the sand from running into the tunnel and undermining the embankment. When this seal has been placed in a manner that will be explained, 3-in. planks in 9-ft. lengths are driven over the top brace of the foremost bent, against which the seal rests. These 9-ft. planks are driven with a slight inclination upward so when they have penetrated until their rear ends are under the second foremost bent, their front ends are over the site of the next bent to be placed and clear the top brace of that bent 8 in. to 1 ft. The planks of the seal across the end of the excavation are then removed one at a time, beginning at the top, and as they are taken out the sand is excavated under the roof sheeting which has been driven ahead of the foremost bent. The planks forming the side sheeting are driven one at a time as this excavation progresses. These side planks are slanted upward to correspond with the slope of the roof planks, and are also pointed so they diverge outward from the center line of the tunnel. They are in 9-ft. lengths in order to form the double row of sheeting on the sides, their arrangement in regard to the bents being the same as in the roof planks. That is, the rear end of each plank is against the inside of the vertical post of one bent; midway, the plank is against the outside of the vertical post of a second bent, and at the forward end is 8 in. to 1 ft. clear of the third bent, each set of planks extending past three adjacent bents.

As the planks forming the seal at the end of the tunnel are removed, the excavation is carried ahead to the site of the next bent to be placed, the material being shoveled into cars, which are pushed out by hand. When necessary, as it usually has been in this work, a seal for the new face is started at the top of the tunnel and carried to the bottom of the latter as the excavation proceeds, the planks being braced temporarily against the bent already placed. After the excavation has been carried forward to the next bent in this manner, the side sheeting driven and the new seal completed, the bent is built up in position. Filler blocks are placed meanwhile between the two rows of sheeting where the latter pass the bent, in order to prevent the projecting part of the outer planks from breaking when the excavation advances further. The cycle of operations is then repeated in this manner until the tunnel has been finished.



Longitudinal Section.

Plan



Section of Bent.

Timbering for Tunnels under Embankment.

The sheeting planks could scarcely be driven by hand in the limited room available, and through the hard driving encountered, so a simple battering-ram device that has been improvised for driving them has proved particularly advantageous. A 12x12-in. timber, 12 ft. long, is fitted with a hook near the middle, by which it can be hung from a chain; the chain is attached to the rear one of two pieces of 2-in. pipe placed across the tunnel about 3 ft. apart, near the roof, and just back of the point where work is in progress. A handle is attached on each side of the ram so two men can swing the latter back and forth and drive the plank. As the plank advances the ram is moved forward to the second pipe. The planks are driven quite rapidly and easily in this manner.

Four or five men work in the tunnel while the excavation and timbering is in progress, one man frames the bents and timbering outside the tunnel and a foreman is in charge of the work. With this force an average of about 4 ft. of tunnel is completed each 10-hr. shift.

The construction of the culvert was not started until the tunnel had been finished. The invert of the culvert is 18 in. thick at the sides and 12 in. thick at the middle. The sills of the bents are imbedded in the concrete and two pieces of light rails are placed horizontally between each two sills as reinforcement. The top of the culvert is also reinforced with light rails. In construction, the invert is built first for a considerable length, after which the side walls and the top are finished at one operation. The concrete of the sides is extended back to the outer row of sheeting, and in order to accomplish this the inner row, which is formed by the rear half of each set of 9-ft. planks, is removed by cutting off the planks just back of the middle bent covered by each set. As the culvert is finished, back filling is rammed between the top of it and the sides and roof of the tunnel lining, so settlement of the embankment will be prevented when the timbering decays, as it may do eventually.

The concrete materials are delivered along the track on the embankments in a special form of quick-dumping car, so very little delay is occasioned to train movements. A concrete mixer is set up at the mouth of the tunnel, the materials being delivered down the side of the embankment in chutes to storage piles at the mixer.

The cost of the tunneling, including all labor charges and the cost of timbering, was about $7 per foot for the 8x8-ft. tunnel. Laborers were paid $2.25 and the foreman $3 a day. The 3-in. maple planks used for sheeting were rough heartwood, costing $12 a 1,000 ft. The timbers for the bents were Norway pine or tamarack in logs, except that they were cut at each end for framing. The cost of the concrete culverts is not available at this time, but is probably at least no more expensive than such work done in the open, as no outer forms were required.

This work is being done under the direction of Mr. R. C. Young, chief engineer of the Lake Superior & Ishpeming Ry., to whom this journal is indebted for the information from which these notes were prepared.

Book Notes.

Every few weeks an inquiry reaches this journal for information concerning plunge baths, particularly their heating. A little book that answers these questions in much detail has just been written under the title of "Swimming Pools" by Mr. John K. Allen. It describes their construction, water supply and heating, and gives detailed directions for the selection of apparatus for the latter purpose. A number of installations of different types are illustrated and altogether the book is a decidedly good one. (Chicago, Domestic Engineering, 50 cents).

A large number of tables in regular use by the engineering department of the Trussed Concrete Steel Co. have been published with explanatory text under the title of "Kahn System Standards." Although some of the pages are trade arguments, the volume is esentially a handbook of the practical calculation and application of reinforced concrete, of marked value to those using this system of reinforcement. The beam and girder tables are based on the following assumptions: (1) A section plane before bending remains plane after bending. (2) The tensile strength of the concrete is entirely neglected. (3) There are no initial strains in the beam. (4) All shearing strain is provided against and there is no slipping between the concrete and steel. (5) The modulus of elasticity in concrete is constant. The tables are extended to include T-beams and also beams in which the design is limited by the compression of the concrete and the full tensile strength of the steel is not developed. Reinforced concrete floor slabs and the floors composed of tile and reinforced concrete are covered by the tables, and there are special beam tables of safe loads uniformly distributed which are arranged like the tables of steel beams issued by rolling mills. The tables of column strength relate to hooped and unhooped types, and those relating to footings are unusually extensive. The book also contains the tables of earth, grain and coal pressures which are used by the company's engineers, a digest of part of the requirements of the building codes of New York, Chicago, Philadelphia, Boston and San Francisco, and drawings and tables of standard highway and railroad culverts and arches. At the end there are some excellent rules for construction and tables of the amount of material required for mortar and concrete of different proportions. (Detroit, Trussed Concrete Steel Co., $1.50.)

A complete description of the new water works of the Swedish capital, written by Major F. V. Hansen, gives an account of an undertaking containing many features of design and construction different from those usually adopted in the United States. The title of the book is "Stockholm's Nya Vattenledningsverk vid Norsborg," and it is published by K. L. Beckman, of Stockholm. The supply is drawn partly from wells and partly from a large lake. The well water is treated to remove the iron it contains and the lake water is filtered, slow sand filters roofed over with steel trusses and skylights being employed. There is a pumping station connected with the works, a long tunnel, a covered reservoir, inverted syphons, a reinforced concrete aqueduct and many less important features of interest. Their details and cost are stated quite completely and the text is illustrated with many engravings and plates.

The second section of the third part of the cyclopedic "Handbuch fuer Eisenbetonbau," published under the editorial direction of Dr. F. von Emperger, is particularly useful. It opens with an explanation of the theory and design of reinforced concrete reservoirs and vats, underground, surface and elevated, for holding water, wine and other liquids. So many elevated towers are now being considered that the portion of the book outlining the steps to be taken in computing their parts is likely to prove useful to a large circle of readers. The author, Mr. Richard Wuczkowski, of Vienna, also describes many completed structures, a number of them being in the United States. The next division of the book, by Mr. Fr. Lorey, of Bernburg, is a description of the design, construction and test of reinforced concrete pipes, conduits and aqueducts, ranging in size from small sectional pipe carried in stock like vitrified clay sewer pipe to large ornamental aqueduct bridges. Mr. B. Nast, of Frankfort, contributes a short chapter on the uses of reinforced concrete in mine shafts, tunnels and large subways, and Mr. A. Nowak, of Vienna, continues the subject, closing with a description of some unique snowsheds and avalanche galleries. The book is profusely illustrated. (Berlin, Wilhelm Ernst & Sohn, 15 marks).

The voluminous paper on "Elevating and Conveying Machinery in Steel Works and Rolling Mills," read by Prof. G. Stauber at the annual meeting of the Society of German Iron Masters last May, has been reprinted in pamphlet form for sale at 4 marks by August Bagel, Dusseldorf. The illustrations are profuse and cover a great range of machinery, particularly heavy apparatus like special cranes, machines for handling ingots and the like.

A small handbook of the principles governing the design of water power and water supply works, apart from machinery and reservoir details, has been written by Mr. Ferdinand Schlotthauer under the title "Ueber Wasserkraft—und Wasser-Versorgungsanlagen." Its methods are those well known through the famous "Huette" pocket-book and the "Handbuch der Ingenieurwissenschaften." There is nothing particularly novel in the contents, but it explains clearly the steps to be taken in designing small power canals, weirs, penstocks, aqueducts, syphons, and systems of street mains. The engineer who is not looking for details of theory and the design of large works where the minor points are so important that the engineering work becomes complicated, will doubtless find this little book sufficient for his needs. (Munich, R. Oldenbourg).

Students of mill architecture will find a large amount of valuable information on the 25 plates of details in Mr. H. W. Morton's "Details of Mill Construction." This is a quarto volume of drawings for actual mills or sketches made from measurements of existing structures. All the text is lettered directly on the plates with the exception of a few general statements which the author gives in his preface. All drawings have been endorsed by the Boston Board of Fire Underwriters as being in conformity with their requirements. Some of the details call for much less expense than others, so that the reader has quite a range of choice in the designs for the same purpose. The sketches are useful to designers of stores, warehouses, power stations and stables as well as mills. (Boston, Bates & Guild Co.).

Messrs. Henry C. Horstmann and Victor H. Tousley have written a pocket-book entitled "Electrical Wiring and Construction Tables" which seems to be well adapted for the use of foremen on work. It gives direct and alternating current wiring tables and diagrams and an explanation of their use, a chapter on methods of obtaining the utmost economy in laying out wiring jobs, numerous conduit diagrams and a large amount of miscellaneous information relating directly to wiring. The book is small enough to be carried readily in the pocket and is bound in limp leather. (Chicago, Frederick J. Drake & Co., $1.50.)

The U. S. Forest Service of the Department of Agriculture has recently published two books of general interest to those who appreciate the importance of greater care in the use and maintenance of our timber resources. These books show how many advantages will eventually result from the system of federal control over the important timber tracts now known as national forests. Some people have the idea that these lands are great restricted picnic grounds into which the public may intrude only in fear and trembling, prohibited from breaking a branch or culling a posy. As a matter of fact, the homeseeker can travel all through a national forest, pick out the agricultural land he desires, settle there and live for the rest of his years on this tract. The policy of the Forest Service is to encourage such settlement, for it enables more men to be secured promptly to fight forest fires. prospecting and mining go on just as before, and uncontrolled lumbering alone is stopped. The timber is not made useless, however, for not only is it given away to the home-builder and to the prospector, but it is sold for commercial purposes as well, provided the trees may be felled at the time without interfering with sound forestry principles. All these things are explained in considerable detail in the "Use of the National Forests," a well illustrated handbook which contains also considerable information regarding the location, extent and character of the various reservations. The reader who desires to become familiar with all the regulations issued by the Department of Agriculture to govern forest reservations will find the complete text in the "Use Book," which is an annotated collection of these rules and instructions showing every detail of the conditions under which the public may make use of the national forests.

The water, gas and drainage piping and fixtures that are used in buildings are governed generally by the rules of the local building department. These rules are necessarily drawn up to insure sanitary conditions when the job is done with the cheapest materials in the least exensive manner possible to satisfy a minimum hygienic standard. This grade of work and materials is not that desired by most owners, and for this reason it is not possible for them to rely on the specifications of the building department or the inspection of its employes. It is therefore desirable to have the specifications for such work prepared by somebody who is thoroughly familiar with the various grades of installations and to have the job under constant competent inspection as it progresses. This is likely to save money and future annoyance to the owner in the long run, and the reason it has not been done better in the past is the fact that only a sanitary specialist, plumber or fitter really knows where to look for intentional or careless or ignorant mistakes. In order to supply just such information Mr. William Paul Gerhard has prepared a book entitled "The Superintendence of Piping Installations in Buildings," in which he gives the results of an experience covering more than 25 years in planning and supervising such work. The book is prepared so as to be equally useful to architectural superintendents, plumbing and health inspectors, plumbing superintendents and the owners who wish to assure themselves that the sanitary work done on their property is properly executed. The book takes up the superintendent's responsibilities in the order in which they come to him, starting with the sewer, gas and water connections from the street and passing through the rough work and the setting of fixtures to the tests and the preparation of final records and plans. There is a very general need for such a book and this one answers the reuirements admirably. (New York, McGraw Publishing Co., $1.00).

The American Society of Mechanical Engineers, 29 West 39th St., New York, has reprinted the presidential address of Mr. F. W. Taylor on the "Art of Cutting Metals," and is selling it bound in cloth at $3. The demand for this address has been very great, and the number of "Proceedings" in which it first appeared was exhausted directly after the last annual meeting.

The West Virginia Geological Survey has issued a special report on the topography, geology and mineral resources of Ohio, Brooke and Hancock Counties. It is written by Prof. G. P. Grimsley, assistant State geologist, and is sold at $1.50 at the Survey office at Morgantown.

The nature of matter has been a fascinating subject for the philosopher and physicist, the thinker and the worker from the days of Democritus and Lucretius down to the present hour. And, indeed, it may safely be said that at no time in the history of scientific discovery was greater activity displayed in the study of problems relating to the constitution of the ultimate forms of matter than in recent years. Were proof needed, it would be afforded by every one of the 230 pages of Dr. Oliver Lodge's "Electrons." This volume shows a clearness of exposition which leaves no lingering doubt in the mind of the reader. The author has done pioneering work in the electronic field and has discussed proposed solutions of outstanding difficulties with the leaders of scientific thought at home and abroad, so that this latest work of his is sure to command at once the confidence of the reader, even when dealing with the more speculative parts of the subject. That the "electron" has opened up not only a new chapter, but also a vast domain in general physics will be evident from a glance at some of the titles of the successive chapters: Nature of chemical and molecular forces; increase of inertia due to rapid motion; the electron theory of conduction and radiation, etc.

Though several good works on that smallest of entities, the electron, have recently appeared, no student of physical theory can afford to be without this volume. (London, George Bell & Sons, 6s.)

Letters to the Editor.

RAILWAY TOPOGRAPHY.

SIR:—In your number of August 24 a correspondent who signs himself "Transitman" makes some interesting observations on the subject of topographical work on railway surveys. He very properly lays stress on the fact that the aim should be to secure the topography with the desired accuracy at a minimum cost, which leads him to the opinion that the methods followed in open prairie country are not applicable in the mountains. With this opinion a good many of us who are engaged most of the time on location will probably agree, yet there are two things to be considered which your correspondent did not mention. The first of these is the very rough nature of considerable location, made for companies of limited resources or for the consideration of directors who have no intention of ordering construction for some time to come except under rather unlikely conditions. The second thing that must be considered is the difference in men, for I have seen a few "natural" topographers whose skill was so great that it is safe to say one of them with a single assistant will map as much topography as an average four-man party and with equal accuracy. The first man of this type I saw was engaged on a party in western Iowa which was trying to locate a line now a part of the Burlington system. The country was the worst I ever traversed, although it did not look particularly bad, and I have often wondered if the Burlington engineers who have been engaged of late years in the improvement of those old lines leading to the Missouri have the same feeling of respect for the twisting gullies of that district that I have maintained for a generation as the result of early experience there. The country is much worse than real mountainous districts, because, until it is all covered by a topographical survey like those of some States where the U. S. Geological Survey has been active, it may be questioned whether it is really possible to know just what is the best location. In mountainous districts, the salient peaks and passes furnish a guide that enables the possible lines to be reduced speedily to a few.

Where the country is difficult, your correspondent is perfectly correct in stating that of all field positions that of topographer requires more experience and greater exercise of judgment than any save that of locating engineer or chief. The late A. M. Wellington once wrote that "in country at all rough the topographer fills the most responsible position on the party below its chief, and should so rank." If he is not competent the map will be of little value, or it will be extremely costly on account of the time put on the topographical work by members of the party engaged for other work. In consequence of this fact, I have always endeavored to obtain permission to use my judgment regarding the detail of topographical work, so that where a poor man is employed on it the amount taken in easy country shall not be so great as to hold back the whole party. This sounds like makeshift work, yet on some surveys it is entirely proper. Where directors will not furnish funds for engaging thoroughly competent men, but demand results on a certain date, they cannot expect these results to be as detailed and as accurate as those obtained on the excellent railway surveying lately done by two great companies in the district from which your correspondent writes.

It seems to me that in a good deal of mountain country in which I have worked there would be no call for such a large force on topography as the writer of the letter advocates. Some mountainous districts are not at all difficult to map expeditiously, for while the slopes are steep, they are uniform and not covered by such a growth of brush that there is any difficulty in seizing upon their contour. In many such districts two men trained in the work are certainly enough. There is no use in getting results to a greater degree of accuracy than will be clearly shown on the map, and I have noticed quite often lately that this unnecessary accuracy seems to be considered essential. Paper locations are extensively made, and some companies are stated to make their final location practically a topographical proposition, the maps of the preliminary party being sent back to a main camp where the final line is plotted on them and then at once run in on the ground. I know nothing about this method, and have never even talked with anybody who has been on work where it is employed, although great claims for its speed and economy have been made. It demands special skill on the part of the topographical men, for they must be both speedy and accurate in order not to delay either of the field parties, and I should like very much to learn more about the working of the method.

There is a feature about topographical work that possibly is overlooked at times. The permanent addition to a party of every extra man means more than the wages of that man, for his subsistence and quarters have to be considered, and the fact that every extra man means so much more delay in getting about. Everybody who has lived in the field for a number of years knows that small parties accomplish more per man than large parties. It is for this reason that I should much prefer to have two good men on topography in difficult country than four of average ability. I have rarely found it necessary to put transitmen on topography where the regular topographer was really skilled, although at times I have had the transit party run lines near both the uphill and downhill sides of the strip so as to reduce the distance the topographer had to work out from a surveyed line. This is equivalent to sending help to the topographer from other members of the party, but it gives him help in such a way that he is not made to appear slow in his work, and the instrumentmen are thereby taught that the work done by the topographer must be borne in mind by them. A very little of such double-line running is necessary with a good topographer, and I believe its cost is far below that of a permanent extra man in the organization, except where the country is broken. Possibly this opinion may be due to the unwillingness of old men to change their views, but it is nevertheless the result of a lifetime of experience in railway surveys and associated work.

Very truly yours, RICHARD LEA.
Los Angeles, Aug. 26.

THE POWER PLANT OF A SMALL FLOUR MILL.

SIR: My attention has just been called to an error in an article with the above title in your issue of July 20th, describing improvements made in the power plant of a flour mill at Washington, Mo., which are stated to have resulted in a fuel saving of 120 per cent., a truly astonishing result. The data for this article were prepared in my office and it is possible also that the 120 per cent. figure was made here. The original coal consumption was 43.5 lb. per barrel of flour; after improvements, 19.6; saving, 23.9. This is 122 per cent. of the final and not the original consumption. The saving over the original consumption was 55 per cent., which is, of course, the figure which should have been used. That the statement should have been made in this shape, and was furthermore overlooked when I read the proof, is one of those inexplicable occurrences which sometimes tend to our confusion in spite of the greatest care and watchfulness.

Very truly yours, WILLIAM H. BRYAN.
St. Louis, Aug. 28th.

GRAPHITE LUBRICANTS.

SIR: In your number of July 22 you print the following: "The United States Graphite Co., Saginaw, Mich., has developed a lubricating graphite in which the graphite is held in suspension in oil sufficiently long for it to perform its purposes when fed through oiling pipes. Amorphous graphite reduced to an impalpable powder is used, one teacupful of it being mixed with about a pint of oil."

This gives the reader a wrong impression of the lubricating graphite which we prepare. This differs from the ordinary flake graphite in that it is an impalpably fine powder, air floated and gritless which, when mixed with lubricating oils in the proportion of one teaspoonful graphite to the pint of oil will feed through lubricator tubes without clogging and remain suspended in the oil sufficiently long to perform its functions.

Your notice states that a teacupful should be mixed with a pint of oil whereas the correct proportion is a teaspoonful. And should any of your readers try to use the same in the way you recommend, the results would be very disastrous to them and would tend to hurt the sale of this lubricant.

Very truly yours,
UNITED STATES GRAPHITE CO.